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TRANSLATION

THE FIRST ASTRONAUTS AND THE FIRST SCOUTS OF
OUTER SPACE

By

M. A. Gerd and N. N. Guroukiy

FOREIGN TECHNOLOGY DIVISION



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UNEDITED ROUGH DRAFT TRANSLATION

THE FIRST ASTRONAUTS AND THE FIRST SCOUTS OF OUTER SPACE

BY: M. A. Gerd and N. N. Gurovskiy

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In all probability it will not be too long before people will be able to visit other planets in the solar system. But before man will be able to set foot on an unknown and unfamiliar planet, a "scout" will have preceded him. This "scout" may possibly be a dog or some other animal. The name of one of these "scouts" - Layka - is now known to the entire world. We have the amazing results obtained through the experimental launchings of animals aboard space vehicles and rockets as well as the remarkable results from the historic flights of Yu. A. Gagarin and G.S. Titov. It is the purpose of this book to tell of the preparation for these flights as well as to provide some data on certain of the scientific results.

FROM THE EDITOR

The flights of Yu. A. Gagarin and G.S. Titov into outer space became possible only as a result of the achievements of our own science and engineering. Scientific investigations in various directions were carried out in our country daily for many years in order to lay the groundwork for a manned flight into outer space, and this work provided an accumulation of the required data for this program. In cosmic flight any living organism is affected by a number of unconventional factors which prevail within the medium in which this organism finds itself, i.e., cosmic radiation, weightlessness, acceleration, low barometric pressure, pronounced temperature fluctuations, noise, vibration, isolation, etc. The effect of these factors on an astronaut cannot possibly be studied under terrestrial conditions, since the majority of these cannot be reproduced artificially. The many cosmic factors affecting a living organism simultaneously can be studied only under the conditions prevailing in an actual flight into outer space. In order to carry out space flights we need facilities and equipment which provide and support normal life conditions in the capsule of a space vehicle and guarantee absolute flight safety.

In view of the tremendous significance of these investigations, and because of the risk and untried nature of the experiments, it was deemed impossible to undertake the conquest of outer space with the immediate dispatching of a man into the cosmos aboard a rocket vehicle. Before this could be contemplated, a number of biological investigations

involving animals would have to be carried out, as a preliminary stage, preceding the penetration of man into outer space. Dogs were selected as the biological "subjects" which were to be placed aboard rockets and sent out into outer space. This selection was dictated by the fact that the physiology of dogs has been thoroughly studied and they can be trained easily to live under the conditions of a scientific experiment. These experiments with animals made it possible to obtain valuable scientific data on the basis of which the security of a manned flight into the cosmos could be assured.

In this offering the reader will find a discussion, in popular-science form, of all the basic projects involving animals during their training for space flight (Parts One and Two). In Part Three of the book you will find a discussion, in popular-science form, of the problems involved in the selection and training of the astronauts, as well as some scientific data that were derived from the flights carried out by Yu. A. Gagarin and G.S. Titov.

Thus with respect to space flights the book touches upon many scientific problems that are associated with the introduction of those changes in the organism and behavior of animals and in the physical and psychological condition of human beings which would be brought about by specific preflight-training factors and the flights themselves. The book presents an over-all picture of the various investigations that were intended to provide for the normal functioning of astronauts during flight and for the transmission of information on such matters as the vital functions of their organisms, their behavior, and their psychological condition. The space flights that were carried out by Yu. A. Gagarin and G.S. Titov were the first landmarks on the long and thorny path of the conquest of outer space. It is probable that any new route to be followed by a space vehicle will require an entire series of

biological experiments involving animals in order to secure the safety of the flight and, therefore, it will be of particular interest to the reader to learn about the great work of Soviet scientists in the experiments on animals, which prepared the way for the first flights of man into outer space.

It is not the purpose of this book to discuss the design of the space vehicles and systems which provided for the normal functioning of an astronaut during flight. These problems, which are of great interest, have yet to be described.

Professor V.I. Yazdovskiy



INTRODUCTION

The achievements of our space engineers are great. On 4 October 1957 mankind was astounded by a report from the Soviet Union that the first artificial satellite of the earth, weighing 83.6 kg, had been launched. Now this no longer seems a great weight: we have already become accustomed to the great tonnage of the satellites and space vehicles being built by Soviet scientists, engineers, and workers. On 3 November of that same year the second satellite, weighing more than the first by a factor of 6 (508.3 kg) was launched. Thus began the era of the conquest of outer space.

These flying craft which cover hundreds of thousands of kilometers in the infinite space of the universe at colossal speeds represent one of the most outstanding accomplishments of contemporary engineering. Even if one is unfamiliar with all of the details involved in the solution of the difficult technical problems that are associated with the penetration of outer space, it is possible to imagine the knowledge and energy that is required in order to arrive at a practical solution to such tremendous problems.

However, Soviet science was not content to stop with these launchings. The payloads sent into the distant reaches of outer space are constantly increasing. Thus, for example, the weight of the third artificial satellite of the earth, launched on 15 May 1958, came to 1,327 kg. The first cosmic rocket (2 January 1959) weighed 1,472 kg. On 14 September 1959 a rocket weighing 1,511 kg, carrying the pennant of the

Soviet Union, reached the surface of the moon. In October of 1959 the third cosmic rocket, weighing 1,553 kg, was launched. On 15 May 1960 the first satellite-vehicle with a capsule equipped with life systems for the normal functioning of a man was launched into an orbit around the earth; this vehicle weighed 4,540 kg.

These space vehicles are penetrating ever further and deeper into outer space. The rocket which circled the moon had penetrated to a distance of more than 400 thousand km from the earth. One would have to drive in a car for about a half a year, at a speed of 100 km/hr, in order to cover this distance. It is difficult even to conceive of such a distance.

But it is not the wonders of engineering that we are discussing here.

Before Yuriy Gagarin and Gherman Titov carried out their heroic flights about the earth, a number of experimental animals had been sent aloft into outer space several times and returned safely to earth. This was accomplished primarily through vertical launchings of rockets which acted as deep but short-duration probes of the upper layers of the atmosphere and served to reconnoiter outer space in the immediate vicinity of the earth. It was during the orbital flight of Layka - a space flight in the full sense of this word - that all of the "cosmic" factors referred to earlier acted on an animal for an extended period of time.

The second satellite-vehicle (weighing 4,600 kg) was launched into orbit on 19 August 1960. The capsule of this vehicle, equipped with all the systems required for the forthcoming manned flight, carried a number of experimental animals, including the dogs Belka and Strelka.

No matter how miraculous space engineering, its fundamental and final purpose is to deliver man to the celestial bodies. After the

flights of the dogs into the cosmos, the achievement of this goal became the urgent and scientifically practical assignment of the day.

It may appear to the reader that if the engineers were able to launch a rocket into outer space, it should not be so difficult to have the rocket carry an animal or a man. But at the same time people on earth frequently have difficulty in even imagining the unusual things that can happen to an unprotected organism at great heights. In this connection we are reminded of a point in the book written by the experienced American pilot Bridzhmen [sic]. He became keenly aware of the dangers awaiting him at great altitudes only after seeing a popular-science film in which the death of animals under similar conditions was shown and the reasons explained. Only then did he understand how important it was to learn the use of the technical and medical facilities that would protect people from the dangers of great altitudes.

These dangers are set to ambush the astronauts from all sides.

Science did not learn of these dangers all at once.

On 15 April 1875 three courageous French researchers made a balloon ascent. Suddenly they felt themselves growing extremely weak; seconds passed and these researchers were engulfed in a state of psychological and physical apathy. The balloon continued its ascent and attained an altitude of 8,000 m, thereupon beginning its descent on its own. All three lost consciousness during the flight, and two were dead by the time the balloon reached the ground; the survivor recovered and described the flight.

At that time the factors responsible for this tragedy could not be ascertained, since people had little idea of the significance of the atmosphere and how it changes with altitude.

The atmosphere of the earth is a mixture of gases, and this mixture includes nitrogen, oxygen, carbon dioxide, as well as inert gases.

Imagine a column of air with a base area of one square centimeter and a height equal to the thickness of the atmosphere layer; this column will press against the earth with a force of 1.033 kg. This force can be balanced by a column of mercury having the same base area but only 760 mm in height. It was this indicator that was selected as the so-called normal barometric pressure. It is quite clear that with altitude the column of air diminishes in size and, consequently, the barometric pressure is reduced as well. In a single cubic meter of air we find fewer molecules of oxygen, nitrogen, and the other gases.

With a substantial reduction in the quantity of available oxygen, there is no longer enough to saturate the blood with oxygen to the required limits and a shortage of oxygen can also be detected in the tissues. The organism begins to experience that state known in medicine as "oxygen starvation - anoxia." The central nervous system is most sensitive to a shortage of oxygen. It is here that oxygen starvation shows itself first. The Frenchmen were unable to breathe oxygen and that is why they became sleepy, apathetic, paralyzed and, finally, lost consciousness entirely.

The dangers to an organism that has adapted itself to life at a certain atmospheric pressure are associated with the changes in this pressure. What will happen to animals if this pressure is unexpectedly and sharply reduced?

Round and brilliantly glistening bubbles will quickly appear in the tissue and among the muscular fibers and vessels. This is a gas and it consists primarily of nitrogen. The gases dissolved in the blood and fluids of the organism begin quickly to leave the solvents as the pressure drops. If not exhaled through the lungs, they form bubbles. These gas bubbles push cells apart, lock blood vessels, and press against nerve ends. Sometimes these disturbances can have serious consequences,

resulting in paresis and paralysis. Only the appropriate protective measures can save an organism from these so-called decompression disorders.

There is yet another danger that is associated with a drop in pressure at great altitudes. Imagine that the lymph, and the tissue and cell fluids begin to boil much like water when it is heated. It is clear that the organism cannot exist in this state. This initially strange phenomenon can be explained by a well-known physical concept, i.e., the boiling point of liquids diminishes with a reduction in the pressure above the liquid. At an altitude of 19,000 m and higher the barometric pressure is so low that liquids begin to boil at a temperature of about 37°C , i.e., at the body temperature of a human being.

Certain states of illness associated with the action of cosmic factors set in unnoticed, at first producing no uncomfortable sensations, developing for weeks, months, and even years.

These ailments may begin as a result of what might seem to be insignificant changes. We have before us a small "astronaut mouse." This mouse has spent many days at an altitude of 27.5 km. The color of its fur is unusual; it is no longer white, as is normal for laboratory mice, but rather its fur is black. Thus we can easily notice those hairs which have turned grey during the time that the animal spent in outer space. There is a triad of such hairs on a small section of the mouse's head, and on the side, for 4 mm, we find twelve such hairs.

Such greying indicates that certain changes have taken place in the skin of the animal under the action of so-called cosmic rays.

Cosmic rays are elementary charged particles which move in the magnetic and electric fields of interstellar space at colossal speed. The origin of these cosmic rays has as yet not been determined.

In moving through cosmic space billions of these particles

find their way to the earth's atmosphere. Here they undergo numerous conversions which, in the final analysis, cause the ionization of the air and the formation of so-called secondary cosmic rays (fragments of atoms and nuclei, electromagnetic radiation).

These cosmic rays reach the earth in an extremely weakened and altered form. Nature therefore did not have to adapt terrestrial organisms to the action of the primary cosmic rays.

The primary and secondary cosmic rays destroy the nuclei of the atoms in live tissue or in any other substance, knocking electrons free, i.e., ionizing the tissue. This is the explanation for the greying of the hair on the mouse at those points where the hair follicles were destroyed by the penetration of a cosmic particle. There is no live substance that can withstand the penetration of the primary cosmic rays. They can penetrate to the heart of an organism and, probably, damage the nervous system, the blood, and the blood-producing organs, as well as stimulate the growth of malignant tumors, and shorten life. It is not by chance that scientists use such words as "may" and "probably," but rather the fact that the action of the primary cosmic rays on an organism has not yet been thoroughly studied, and it is extremely difficult to reproduce the spectrum of these rays on earth.

Thus cosmic radiation may represent a tremendous danger, and it is the task of science to study the effect of these rays, to neutralize their effect, and to protect the life and the health of the future astronauts.

In addition to cosmic rays, there are other invisible forms of emission that may prove to be dangerous (for example, the shortest of the ultraviolet rays, etc.). The atmosphere of the earth protects us against the destructive effect of this type of radiation; the atmosphere serves as a reliable shield and either reflects or retards the

penetration of this form of radiation to the surface of the earth. Many of even the simplest of materials serve as solid obstacles for this form of radiation. Therefore a man dressed in a spacesuit, for example, is protected against this radiation. The outer shell of the spacesuit may gradually be destroyed by the action of this form of radiation and it must therefore be made from a special material.

There are negative effects on the human organism that are also associated with the motion of the rocket. The rocket rapidly rises into the sky, in a period of only a few seconds. The entire flight involves only several minutes. During this short period of time the rocket can climb to an altitude of 200-400 km. During the take-off, the organism finds itself under conditions that are completely unknown on earth. The weight of a five-kilogram dog increases many times (this is the action of acceleration during the take-off). The animal is subjected to vibration, noise, and finally enters a state of weightlessness. Can this living organism withstand these disturbances?

We have not begun to enumerate all of the dangers. But the above should suffice to prove the total impossibility of sending an unprotected organism into outer space.

In other words a number of medical and technical devices must be developed and produced to provide conditions required for the normal functioning of an organism, to protect it, and to transmit information on the condition of the organism. How can these dangerous factors be attenuated? How can life be preserved, how can everything that is required for life be provided? Is this at all possible under the conditions that prevail in outer space?

Now, after the rocket flights with dogs, rabbits, and rats, after the launching of the satellite with Layka, the flights of the satellite

vehicles with Belka and Strelka, Chernushka and Zvezdochka, after the flights of Yu. A. Gagarin and G.S. Titov, it is clear that Soviet science has successfully resolved these problems.

In order to provide all of the necessities for the space flight of a higher being, an entire range of special devices has been developed, insuring the safety of such a flight, and raising the ability of the organism to withstand the unfavorable factors involved in such a flight. With this purpose in mind a great many experiments were conducted over a period of several years and many of these experiments are interesting now only from the historical point of view.

By the way, when we speak of the conquest of outer space by people, the word "history" must cause one to smile. In the study of this history there is no need to wallow in the dust of archives. Here we have history passing before our eyes: many in the ranks of the first scientists who laid the groundwork for these flights are still working on these problems, and the others are still fresh in the memories of our contemporaries.

The history of cosmic flight begins with the work done by K.E. Tsiolkovskiy. Half a century ago, at a time when there were not even any airplanes, this outstanding Russian scientist laid the foundation for the theory of reaction motion and proposed the design of a new type of flying craft. Tsiolkovskiy is also credited with the first experiments directed at the clarification of the problem of whether life is possible under the conditions prevailing in a rocket in motion.

The immediate preparation for cosmic flights was begun in our country in the postwar period. In the 10 to 15 years since the end of the war the grandiose path that has been covered may in truth be referred to as historic. This designation applies not only to the technical problems involved in the mastery of outer space, but it applies equally

to such fields as biology and medicine. As early as the 1940's a small but solid unit of biologists, doctors, engineers, technicians, and laboratory workers worked stubbornly and persistently in the army of Soviet scientists, conducting numerous experiments whose purpose it was to resolve a number of biological problems associated with the flights of animals, and subsequently with the flight of man into outer space.

For the dogs in the streamlined body of the rocket designed for high-altitude flights they prepared a "piece of earth" - a hermetically sealed capsule - a small enclosure in which the required air composition was maintained, into which oxygen was fed, from which carbon dioxide was removed, and in which the required barometric pressure was maintained, etc.

The hermetically sealed capsule that had even been proposed by Mendeleev became an everyday item in contemporary aviation and was, in part, taken over for space flights.

For space travel, however, new types of hermetically sealed capsules were required. The walls must be strong enough to withstand great pressures and, at the same time, prevent the passage even of gas molecules. The walls must be this strong, since the capsule (with normal atmospheric pressure on the inside) will find itself under conditions of no atmosphere and no external pressure. How strong must the capsule be to prevent its exploding like, for example, a deep-water fish that is brought to the surface of the sea.

Time after time, new designs of such capsules were thought out and test launched. They are light, extraordinarily strong, and of various shapes and sizes. Some resemble large and beautiful glistening silver boxes, others are in the shape of a truncated cone, and a third is made in the shape of a sphere mounted on special supports. In addition to hermetically sealed capsules, a variety of hermetic spacesuits were

designed to follow the shape of the particular animals in question.

Much effort and energy was required to resolve the problem of how to provide a constant air composition in the chamber which was to be the home of the dogs for an extended period of time, and there were also the problems of how to regenerate the air and maintain a certain pressure. After all, a dog weighing 6-7 kg absorbs 6 liters of oxygen within one hour and exhales 6 liters carbon dioxide and 20 g of water vapors.

There are many and varied sets of instruments to resolve the problem of air regeneration in the capsule. Many of these versions separate the first such device from the last regeneration installation with a special chemical substance which simultaneously releases oxygen and absorbs the water vapors and carbon dioxide.

When you look at this small-scale system, functioning automatically and faultlessly maintaining the required gas composition in the capsule, it all seems very simple. Nevertheless, the development of this device, just as any simple solution to a complex problem, was preceded by a great variety of test versions. Simultaneously, in hundreds of experiments tests were conducted on other devices without which the flight of living beings would be unthinkable. All of these engineering-design operations could be carried out successfully only under conditions of joint effort on the part of engineers and doctors, since the evaluation and checking of each installation was impossible without biological experimentation.

Moreover, an entire system of animal selection and training was developed, the purpose of this system being to raise the ability of the dogs to withstand the effect of unfavorable space-flight factors. In order to train an animal to withstand a certain disturbance anticipated during the flight, attempts were made to reproduce in the lab-

oratory the surroundings in which the dog will find itself in flight, and special pieces of equipment were designed for this purpose. This equipment was subsequently used to simulate any given flight factor. The reactions of the animal organism to these influences were thoroughly studied, and the effect of a number of factors was tested.

All of this made it possible to find, verify, and select the best means of providing for the normal functioning of the dogs during flight, to select the required animals, and to train them for the flight.

In this way was Soviet science able to resolve the first, and therefore the most difficult, questions encountered in the conquest of outer space; it was in this way that Soviet science was able to break through the first barrier to the cosmos.

TRAINING

SELECTION OF DOGS

The selection of dogs for flight training is not a simple matter. We are on the lookout for animals which will simultaneously satisfy a multiplicity of requirements and combine, within themselves, a variety of characteristics. It is extremely difficult to find such dogs.

Much traveling and searching is necessary and at times agreements must be reached with the owners of the dogs. It is quite easy to understand, therefore, the happiness with which the researchers greet each animal that is deemed as suitable for the experiment. The dog is carefully examined and its length and height measured. It is best if the animal has white fur. Moreover, only the female of the species can be used.

The sex of the dogs is included in the number of characteristics on the basis of which the selection of the experimental animals is carried out. The problem of male or female dogs was not raised as a result of any significant or particularly scientific factors, but only because of the so-called "clothing for the dogs."

The expression "clothing for the dogs" sounds ridiculous: what looks like "clothing" is quite unusual and does not serve any decorative purpose nor is it employed to keep the animal warm, but rather it serves the purpose of harnessing the dog tightly in the special capsule and to remove its excretion into a septic tank.

The clothing must be such that the dog can wear them for a long

time, without suffering any rubbing sores. It has not yet been possible to design clothing for male dogs which satisfy these requirements and, therefore, only female dogs could be used in the experiments.

The size of the selected dogs is also quite unusual. Dogs that are only slightly larger than cats are selected for these flights, i.e., their weight must not exceed 6-7 kg.

Dog breeders know of thoroughbred dogs that are small in size. Recall, for example, the toy terrier. This smooth and thin little dog, chocolate-brown or black in color, fits easily into a coat pocket. Then we have another very small animal - the white longhaired spaniel. A dachshund could also be included here. All of these are so-called "decorative" dogs.

These dogs have been bred specially through generations. These animals lived with and were protected by people for hundreds of years. As a result they are used to good food, to live in warm rooms, and to a number of other conveniences.

Such animals are not suitable for flight. This is understandable, since the primary condition for determining whether or not a dog is suitable for these experiments is sound health, high resistance to disease, and the ability to withstand the various unfavorable conditions prevailing in the external medium.

Even mixtures of mongrels and "decorative" dogs failed to satisfy the scientists. Experience shows that the most unpleasant circumstances can arise if such animals were chosen. A dog named Chudo died as a result of a simple hernia operation. Another dog, a cross between a mongrel and a dachshund, suddenly and unexpectedly caught cold and died of pneumonia as a result of a slight drop in temperature, whereas a nonpedigree dog that had been paired with the dead animal withstood the cold without any adverse effect. A cross between a mongrel and a spaniel

also died during an experiment, whereas its partner - a nonpedigree dog - felt fine. In other words, all of the attempts to use pedigree dogs or even crossbred animals for flight training sooner or later proved to be unsuccessful.

Small size and no pedigree? This combination alone is a problem when searching for the dogs needed for experiments. But this is not yet all.

The age of the dogs is also extremely important. A physiological study of the animals showed that the differences in age become apparent during the course of certain physiological processes. Old animals as well as dogs less than a year and a half old are not as well equipped to withstand various disturbances. They do not react well to unfavorable conditions and they are more susceptible to disease. Moreover dogs under a year and a half are usually playful and excitable, characteristics that present considerable difficulties in using these animals for experiments.

On the basis of experience, as well as on the basis of the data available in the literature, it has been established that it is best to select dogs ranging in age from a year and a half (even better from two) to five-six years for purposes of experiments. The age of a dog is determined by its teeth (their color and degree of wear).

The color of a dog's fur is also extremely important. Desirably, the fur should be white; this is associated with the fact that motion-picture photography and television are employed during the flight as one of the means of keeping the animals under observation.

Experimenters have attempted to bleach dog fur with hydrogen peroxide. A black dog nicknamed T'ma [Darkness] walked around for some time with red squares on its back and sides. This was all that the hydrogen peroxide was able to achieve. The pigment which colors the

fur of animals is more pronounced than in a human being and therefore does not lend itself to bleaching.

The scientists must concern themselves daily with the problem of selecting dogs. "Come in and look at our new dog," says the man in charge of the vivarium. Happily he enumerates all of the good points of this new candidate for cosmic flight: "It weighs 5.20 kg, it is white with only a light-yellow spot on its head, its legs are short, and it's a gentle mongrel female." This covers precisely all of the characteristics required. But can a dog like this now be accepted for experimentation? As it turns out, not yet.

After the preliminary selection, based on external characteristics, the selection gets down to more significant factors. All of the preliminarily selected dogs will be subjected to various tests for an extensive period of time and those of the animals which pass these tests with grades of "good" or "excellent" will be classified as astronaut trainees, participants in this great experiment in flight.

For the moment let us leave the problem of the future training of the dogs. Let us consider how these experimental animals are housed and how they are attended.

THE CARE OF THE EXPERIMENTAL ANIMALS

There is a large courtyard. Green lawns and flowerbeds, and wide paved paths winding through pretty white structures. There are many trees. At the rear of the yard there are smaller buildings, a number of workshops, warehouses, barns, high shrubbery, grass, and again paved paths and lawns. This entire area is reserved for the dogs to take their exercise walks.

We can see three dogs, none of them on a leash, circling around a slender somewhat older woman. She walks along the paths into one of the buildings, and the dogs with their noses buried in the fresh green

grass, playing tag with one another, chase after her. Occasionally the woman stops, calling out to one of the dogs that has fallen behind, and it seems as if these are not experimental animals that are strolling along, but rather that some pet dogs are following after their mistress.

Here we see a number of animals trotting alongside a young fair-haired girl with dark eyebrows. One of the animals is busily engaged in sniffing a plank and the grass around the barn, the other are scurrying about the yard. Il'va, as always, is scampering around the legs of the young girl - a laboratory assistant - and does not let her get ahead by more than three paces.

A half an hour later other laboratory assistants are walking other dogs around the yard.

The walking of the dogs is one of the most important parts of their maintenance program.

Each animal is walked at least two times a day. Before the beginning of the experiment these walks are rather long. Those dogs that are not used in the experiments, as a rule, are housed in a well-ventilated enclosure, practically in the open air. Some of these animals are released into a small fenced-in kennel in which they can run around without supervision.

The dogs live in a special enclosure - a vivarium. Here we find a number of almost square wooden-floored cell-like structures raised on meter-high supports. The name of the inhabitant of each of these cells is marked on the structure. Let us read the names that have been written so neatly in chalk - Nochka, Bodraya, Zolushka, etc. Here it is warm, light, and dry.

There is litter in this enclosure - fluffy, thin, and long shavings, straw, and sometimes hay. The dogs sleep on this litter. There are also several bowls here: one for food, the other for water.

Those of you who are not familiar with the life of dogs in a vivarium will doubtlessly feel sorry for them: after all, a small pet dog is forced to live in a cage, much like a wild animal. This impression becomes even more vivid if you happen to see how an animal dashes out of its cage when the door is opened just slightly. But we cannot agree with this feeling of pity.

As a matter of fact the dogs take well to their cages and, returning from their walks, jump into the cage as readily as they leave it.

Sometimes it happens in the following manner. Where is Lepeshka? The vivarium head, in great confusion, is looking everywhere for this dog that somehow ran away from the enclosure. The dog is sought everywhere and finally, saddened by the loss, they accept the fact that the dog has disappeared. However, the enclosure and the door to the cage is left open, just in case. By morning Lepeshka is found to be sleeping peacefully in her cage. She returned home by herself, after an unauthorized trip.

The dogs are fed twice a day.

A caretaker enters the vivarium with a pail, takes a washed bowl from the top of each cage and, using a large ladle, portions out a thick soup of gristle and bone with millet or some other groats. The animals wait patiently at the open door. Then bread, separated into neat slices, is brought up on a wooden tray. Meat is also passed around. The dogs are fed a certain amount of vegetables, and they are given fish oil and milk. This is the normal diet of the dogs. Those animals that are to participate in particularly difficult experiments are kept under a special regime in which they are fed sausage, bouillon, preserves, as well as sweets and vitamins.

Sometimes we can see such events as the following. Gil'da - a golden-colored small dog - is being carried by the director of the vivarium.

In one hand he holds a hypodermic needle, and with the other he neatly breaks open an ampule. A viscose white liquid is injected into the dog's muscle. This is a glucose injection. Gil'da had spent several days in an experimental chamber which people were not permitted to enter and as a result she had eaten badly. As a result she needs a glucose injection. The animals are given special care and examined by veterinarians both before and after any experiment.

The animals are bathed under the direction of a veterinarian or one of his scientific coworkers. The animals are placed into a warm-water bath and two attendants wash them with baby soap. Don't act so surprised, it is baby soap that is used because these animals have skin that is much more sensitive to salts than the skin of a human being; therefore, one can by no means be indifferent to the soap that is used to wash the animals. After the bath the animal is placed in front of a reflector and an electric heater quickly dries out even the longest fur.

THE BEHAVIOR OF THE DOGS

It is extremely important to collect data on the behavior of the dogs in the vivarium, on their walks, during their feeding time, and on their "relationships" to the people around them, and this information is important in order to study the various ways in which the animals react. This information, accumulated over an extensive period of time, aids in the correct interpretation of the reactions of the dogs both before and after the experiments, and it also makes it possible to understand correctly those changes that take place as a result of the various disturbances affecting the animals, in addition to enabling the researchers to determine the type of higher nervous activity of the experimental animals.

Such information is also of general interest. I.P. Pavlov, the great Russian scientist, felt it absolutely necessary to undertake a

study of the natural behavior forms of animals, as well as to classify the unconditioned and conditioned reflexes whose causes had to be determined precisely in accordance with valid scientific descriptions of the behavior of experimental animals.

There is much that is common, as well as much that is unique, in the behavior of dogs. The specific features of the various behavior forms, even under conventional conditions in a vivarium, can be understood only after extensive, thorough, and well-planned observations involving the comparison of many facts.

Let us take a look, unobserved, how these experimental animals behave in the vivarium.

Everyone knows Belka, the first to return from outer space; we find her walking around her rather small estate. She does not move hurriedly, she looks to the sides, sniffs at the familiar odors of the vivarium, stops, and moves into a corner. A noise near the door sets Belka on edge. She quickly perks up her ears and we note that the animal is in that portion of the cage from which the entrance to the vivarium is most easily seen. The instant that this "alarm" proves to be false, this white dog with yellow spots continues her "serious" rounds of the cage.

Many of the other dogs behave just like Belka. Undaunted by the limited space available in the cage, they move extensively. Other animals exhibit relatively stereotyped reactions rather than a variety of motions, and sometimes the motion is even automatic: these animals move identically each and every time, maintaining the same relationship between interval and action throughout.

We are now looking at an active fluffy dog — Malek — well-known for its exploits in vertical rocket launchings; this dog is walking along the forward screen of its little home, and as it reaches the end

of the cage the animal puts its left paw on the step that is there and then, with a studied motion, executes a little hop which turns it around to face the opposite direction. This goes on for a rather long time.

The dog with the poetic nickname Mechta circles her cage repeatedly in stereotyped movements. Pushinka jumps to the left side of her cage, landing on her front paws. In the case of the white smooth Raketa, motor activity is expressed primarily in a pawing motion.

Such specifically delineated movements are so pronounced in some of the dogs that the absence of or change in these reactions forces one to assume some disruption in the vital activity of these animals.

All forms of motor activity on the part of the dogs in their cages are clearly adaptive reactions allowing the animals (and particularly the active animals) to carry out the required amount of exercise for a healthy dog under conditions of limited space.

All of the dogs are particularly active before feeding time. They move excitedly in their cages, frequently turning to and sniffing at the bowl. In some of the dogs these behavioral forms are expressed less vividly; in others, this behavior is more pronounced.

At other times we can see how these animals quietly sit or lie in their cages. Generally, during the day we find them in active sitting or lying positions, rather than in passive positions: muscles are tensed, the body lies on the extremities, the head is raised, or if lowered, then lowered onto the paws. In response to various irritants the dogs quickly turn their head in the direction of these disturbances and jump up.

In observing the behavior of the dogs in the vivarium, scientists encounter many interesting and, at first glance, contradictory facts.

The minute you enter the enclosure in which the dogs are housed, you had better cover your ears. The dogs will greet you with wild and

unrestrained friendly barking. They seem ferocious: their mouths are open, and all their movements are directed at the intruder. Again the animals are in that corner of the cage which is closer to the person who has just entered. Many of the dogs scratch the floor and the bars of the cage with their paws out of impatience. Looking at the animals at that instant, one might think that the appearance of a person causes pronounced aggressive reactions in the dogs. It appears as if the animals are actively preparing to defend themselves against the person who has just entered, giving all indications of readying an attack.

However, don't jump to any conclusion. You will soon be convinced that this conclusion is erroneous. The person has only to approach one of these animals, breathing so fiercely, and an immediate transformation takes place. The dog stops barking and trustingly sticks out her snout, attempts to lick your hand, and becomes quiet as you approach her. All of the movements now express a desire to be close to the person: the animal presses against the screen, squeezes its paws through the screen, and wags its tail.

All of this takes place as the other dogs become seemingly desperate, barking louder and louder. But the dog that has drawn the attention of the human being seems not to hear anything. As you approach another dog, this same metamorphosis takes place. Now the animal that you have just left begins to bark again, louder than before, with particular frenzy.

This is how the majority of the dogs behave. Of course, there are dogs that do not bark but whine. Some of the dogs remain "silent" but follow the person closely.

The reactions described above are indicative of the great excitement of the dogs. But one cannot speak of the aggressive nature of these reactions. From the very beginning these reactions essentially

express the desire on the part of the animals for contact with people: the dogs do not growl nor do they bare their teeth, which would be characteristic of aggressive reactions. The animals do not cower in a corner of their cage as people approach.

It came to the attention of the researchers that any and all unusual irritants acting on the dogs in the vivarium caused the animals to become tense and bring about many motor reactions which are sometimes quite furious, and frequently the dogs will react with a loud unchecked howl. The impression is that the animals are "happy" at any opportunity to howl and move around in their screened enclosures.

When we determine the extent to which a given dog moves within its cage and how much time it spends in a state of relative quiet (sitting, lying), it turns out that each animal exhibits a different relationship between the active and passive forms of behavior. Some of the animals move very much, others much less. The animals also differ in terms of the nature and intensity of their movements which sometimes take the form of violent reactions, while at other times the reactions are quiet but active, and at other times the reactions are sluggish.

A study of the nature and the extent of reactions on the part of various animals in the vivarium makes it possible to subdivide all dogs into three groups: a group of quiet dogs - moving moderately; a group of animals whose motor reactions are generally quite pronounced - excited dogs; and a group of "sluggish" animals.

This subdivision makes it possible to arrive at certain tentative, but valid, criteria for the selection of dogs to be used for various experiments.

The "quiet" dogs must be used in extensive experiments. It was precisely for this characteristic that Layka, Strelka, Belka, Lisichka,

Zhemchuzhnaya, "Chernushka, Zvezdochka, and others were selected from among many dogs. The "excited" dogs are more suitable for short experiments in vertical rocket launchings. It is a good idea to select an active easily excited dog for purposes of developing conditioned motor reflexes. As a rule the required movements are demonstrated more quickly by such dogs.

Thus observations of behavior in the vivarium, as shown by practical work with animals, makes it possible to arrive at some advance idea as to the type of higher nervous activity exhibited by each dog. This preliminary determination is of great practical significance, since it makes it possible to select the proper animal for the subsequent and laborious work that is associated with the training of the animal to function under the conditions of the scientific experiment.

The determination of the specific features in the behavior of dogs is also extremely important from the standpoint of determining the condition of the animals and those of the changes which may occur under the action of specific disturbances.

The little yellow dog with a happy disposition - which is why it was nicknamed Radost' [Happiness] - is an active animal. This dog is extremely mobile, and reacts quickly to all stimuli. But when the dog is placed on a centrifuge, where it experiences the effect of tremendous acceleration, the animal seems to undergo a thoroughgoing change, behaving quite sluggishly on its return to the vivarium, no longer barking, and eating poorly. Such a change in behavior indicates that the dog did not take well to this disturbance.

Thus forms of reaction may be used to diagnose changes in the state of the organism that are hard to ascertain. Behavior is an extremely sensitive indicator. Changes in behavior may indicate the negative influence of a disturbance, whereas other "medical" indicators

remain unchanged.

After the centrifuge experiments, Lisichka first exhibited a pronounced change in behavior, but then as she became accustomed to the effect of acceleration these changes in behavior were less pronounced. The same situation was noted in the case of other dogs as well. This indicates that there is a gradual improvement in the ability to withstand the effect of acceleration, i.e., it indicates that it is possible to train an animal to deal with this factor.

Observations of the behavior of the dogs on their walks are also extremely significant. These walks are vital to the animals, since many of their needs are satisfied at the same time. The dog dashes out of the cage and covers an accustomed path to the lawn. Alone the manner in which this is done points up the stimulating and activating effect that these walks have on the animals. Try to call the dog while this is happening. The dog will react poorly to this summons, and will begin to chase after other dogs at breakneck speed. This will go on for several minutes. Gradually this excited running around ceases. The animal will stop near some object such as a stone, a stump, some planks, carefully sniffing each. Having enough of walking, the dog begins to follow and press close to its master.

Despite the fact that the behavior of all dogs is similar during these walks, we nevertheless detect substantial differences in behavior; as a result it becomes possible to arrive at some judgment regarding the motor activity and the condition of the experimental animals. This is essential, since if we know the conventional behavior of the dog, it can be compared with the observations made upon completion of a rocket flight.

For example, during a rocket flight Otvazhnaya - a dog that had been in outer space several times before - showed no significant func-

tional changes. The dog was not hurt in any manner during the flight, and its appetite was good. Nevertheless, the scientists were quite justified in referring to some disturbance which had acted on this dog during the flight.

Judge for yourselves: always active, quick to respond, Otvazhnaya began to behave differently, and this change could be seen in the simplest forms of her behavior. The laboratory assistant opens the door to the dog's house in order to take the dog for a walk. Instead of immediately jumping out of the cage, as was usually the case, the animal rises slowly, examining the situation carefully before jumping out. Some 12 minutes pass before the dog is out in the field. Otvazhnaya does not run happily, as always, on her walk, she does not bark, and she trots along comparatively slowly, not straying from her mistress, frequently coming to rest at her feet. Only gradually does Otvazhnaya's behavior revert to what it was before the flight.

The change in the behavior of a dog after a flight, and its gradual normalization, indicate that the flight served as a significant disturbance on the organism of the animal.

Thus data on the forms of reaction serve as acute indicators of the general state of the experimental animals after the disturbing effect of strong stimuli.

All of the dogs sleep at night. Here we can also speak about positions, unique for each dog. The well-known Layka frequently slept in a rolled-up position, her head tucked in. The famous Otvazhnaya, Neva, and Belyanka most frequently sleep on their sides, stretching their paws out. Belka and Strelka - the famous astronauts - change position during their sleep.

All of the selected experimental dogs are characterized by the most "well-meaning relationship" to many people. And this is under-

standable. Some of the experimenters train the animal to withstand acceleration, others train the animal to withstand vibration, and still others record the animal's blood pressure. The dog becomes accustomed to those people who work with it for relatively long periods of time. But another researcher may choose the animal, and the first, conversely, loses interest in it. Thus each dog must deal with many people and the dog is confronted with many masters: the animal seeks to be petted by each, is friendly to all, and its eyes follow each of them.

A complete stranger approaches a dog with which the scientists had been working for a long time and which is in the laboratory in anticipation of an experiment. Nevertheless, the stranger has only to look in the animal's direction, make some move toward the dog, and she will reach out for the stranger, her tail wagging rhythmically and methodically against the hard surface of the table. You have only to pet this dog and she is yours completely.

This is an extremely interesting fact. It indicates that when a large number of various people concern themselves with a particular dog, man becomes a somewhat generalized stimulus for the animal. This is the explanation behind the fact that the dog reacts identically to various people.

This "relationship" to people, characteristic to all experimental dogs, is clearly dependent on a number of objective factors. First of all, we have the small size of the selected dogs (the size of the dogs makes weak animals dependent on people whereas larger dogs behave differently). Further, there is no doubt that keeping the experimental dogs in cages plays a significant role. The man on whom the animals are dependent for even a little bit of freedom becomes a positive stimulus for them. A certain role must also be ascribed to the circumstance that the dogs living in the vivarium - animals which for generation upon

generation have always been together with man - find themselves only rarely in the presence of man (the experimenter) and are not spoiled by his attention.

The desire of the experimental dogs to be with people is so great that it cannot be restrained even by the painful and mechanical influences which the dog experiences during the experiments. Take a look, for example, at the behavior of Snezhinka, Otvazhnaya, and Strelka when the laboratory assistant approaches their cages, see how they play up to her and how "happily" they run after her into the laboratory. The dogs are going to be subjected to vibrations on a special vibration-producing installation, they will be subjected to other disturbances, blood samples will be taken, and they will be placed in the capsule. These animals have gone through these experiences several times. But the excitement generated by the sense of freedom in the presence of a human being is so pronounced that it eradicates, in a powerful surge, all traces of these unpleasant influences from the "memory" of the animals. And then, afterward, the dog will be subjected to "torturous" separation from the experimenter, and it will reach out to him and whine if he goes away. As you look at these dogs you begin to understand clearly how pronounced is their desire for contact with a human being.

Despite the fact that the dogs under investigation are "friendly" to all people, each has the desire to have but a single master. It is quite common for the dog to choose a human being which he will begin to regard and treat as her own master.

Many of the dogs love the elderly friendly laboratory assistant who treats the animal particularly well. As she walks down the corridor Linda - a small dog with small spots - trots along with her, Strelka runs along, and Mushka is also there.

Sometimes it is quite impossible to tell on what basis the dog

makes the selection of a master. The famous Belka, even prior to her flight into outer space, selected a tall corpulent woman and remained "true" to her after she had been returned safely to the laboratory. Whenever Belka chances to come upon this person, she plays up to her particularly insistently, failing to react entirely to the summonses of other people, begins to follow in her footsteps, etc., and the dog must therefore be carried away. Neva, Kroshka, and Solnyshko behaved in the same way.

After one of the experiments in which conditions unexpectedly turned for the worse, Il'va - a small animal, not much to look at, with rough fur and black spots on her droopy ears - was taken from the chamber in serious condition. One of the laboratory assistants would take Il'va for her walks, and from that time on the dog literally followed her everywhere. The minute the animal comes out of its cage, it begins immediately to look for its mistress. If the laboratory assistant has gone into a room, Il'va can wait for her at the door to this room for hours.

In speaking of the behavior of the selected dogs, there is yet another point which must not be overlooked. This is the question of the patience of the experimental animals as a clearly expressed characteristic of their behavior. Consider the case in which you have brought a dog for an experiment, dressed it, but everything is not yet ready. The animal is placed on a chair and possibly you may forget about it. It will sit there quietly for an hour, possibly two and more, and it will be alert and follow actively everything that is happening in its immediate vicinity. This combination in a single being of immobility and activity seems almost unnatural and becomes possible only because the experimental work with the dogs has produced in them well-developed inhibitory processes.

The dog is the favorite subject for scientific investigation, since it is both easy and pleasant to work with a dog. In Koltushakh [sic] — the center of the Pavlov Scientific Laboratories — there is a high stone pedestal on which stands a monument to a dog whose merits could not help but be immortalized by Russian physiology. Man's friend since ancient times, this animal remains man's friend even now, in the space age.

Soviet space medicine, unlike foreign investigators of outer space who carry out their experiments with monkeys, selected the dog for experimentation from the very beginning, since it is a modest, reliable, and extremely hardy animal. Because of these qualities and because of their love for man, dogs have rendered and are continuing to render invaluable services in the field of experimental space medicine.

CANINE CLOTHING

Some time ago, a coworker entered the laboratory and announced loudly: "Comrades, Chizhik has escaped from the sealed capsule."

Friendly happy laughter rang through the room: "Some sealed capsule." Indeed, it seems that nothing could be more absurd than the escape of a six-kilogram dog from a sealed capsule into which not even molecules of gas can penetrate.

"Nevertheless, the dog is missing from the capsule," says the newcomer perplexed, but smiling happily. "If you don't believe me, take a look for yourselves."

There is no need to repeat this invitation; we run down the corridor to the building in which the sealed capsule is housed. Several coworkers are already standing at the capsule window. Everyone is looking nervously through the large windowpane, trying to examine carefully the interior of the chamber.

And indeed, the capsule no longer contains two dogs — Irma and

Chizhik - but Irma alone. The second compartment in which Chizhik had been sitting earlier is now empty. Where did the animal disappear to?

How could the dog leave its compartment, when it was dressed in its sanitation-restraint clothing? When you know how and for what purpose these two types of clothing were sewn, this fact becomes simply unthinkable.

The fact of the matter is that the restraint clothing is designed especially to fasten the animal securely in the capsule. The sanitation clothing also serves this purpose.

What kind of clothing is this? How is this clothing designed?

Imagine a little dog wearing a shirt and pants. The shirt covers approximately half the dog's back and has no sleeves. The pants are as short as possible. Straps are used to hook the two parts of the suit together. To the above we can add that this clothing is made of a light silk fabric. The dog looks well-dressed in its glistening green or white suit. Properly fitted and unique, this suit makes the dog look like a circus performer.

Small iron rings have been sewn into the special cloth straps of the restraining suit in the region of the shoulder blades and the small of the back. Four light but strong chains are attached, by means of clamps, to these rings and the other ends of the chains are fastened to the four corners of the capsule. Thus the dog is fastened to the capsule walls from four sides.

If the animal remains quiet, it experiences no unpleasant pressure or pulling from the leashes. The important thing is that the dog cannot now turn over, climb into the food container with her paws, nor can she reach the instruments and gnaw at them.

When wearing the restraining clothing the animals feel as well as without it. They can wear this clothing for many days, and these spe-

cial suits do not restrict the freedom of their movements.

The sanitation clothing is made of soft foam rubber and is worn beneath the restraining clothing. The sanitation clothing also consists of two parts: an undershirt and a pair of unique pants that fit the body of the animal as tightly as a sock. An extremely flexible tube (thus permitting the animal to assume any and all positions) leads from these pants, and the other end of the tube is connected to the inlet to the sanitation tank.

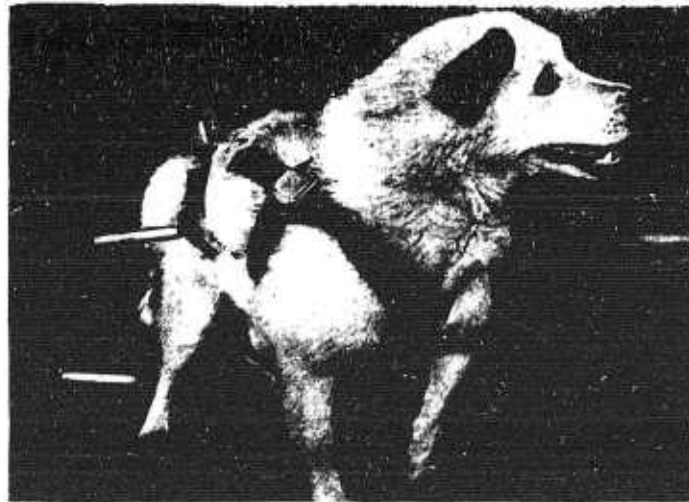
The basic purpose of the sanitation clothing is to isolate and remove the animal's excretion from the capsule. Since it is connected to the sanitation tank, this device simultaneously restrains the dog in the capsule.

It seems entirely improbable that it is possible to escape the tenacious grasp of these restraints. That is why this case of the disappearance of Chizhik caused everybody to be very perplexed, to crack jokes, and to laugh about the miracle that had happened.

A dog is dressed in the sanitation-restraint clothing if the experiment is to last longer than a day. However, if the experiment is of short duration (two, three, or five hours), the animal is dressed only in some light restraint clothing.

All of the dogs which have already experienced various extensive tests are completely familiar with both types of suits. Layka flew into outer space in clothing of this type. This same type of clothing had also been worn by Belka and Strelka, as well as Chernushka and Zvezdochka.

It was no simple matter to design, fasten, and sew a suit of this type, particularly when it has to serve purposes of sanitation. Nature did not intend dogs to wear suits of this type, and also these animals have skin that is much more sensitive than the skin of a human being. Any contact between skin and rubbing surfaces produces sores: reddening,



Belka in her sanitation suit.

swelling, and even open wounds. Special rubber had to be selected, and the seams and edges had to be made soft. The animal's excretion should not seep beneath the rubber and the material, wetting or soiling the dog's skin. After all, this would produce a rash, painful spots, and formation of pus. The clothing on the dog's body cannot, under any circumstances, be permitted to move, since otherwise the excretions will no longer enter the tube.

The elastic tube which was used in the initial sanitation-suit versions was replaced by a soft "corrugated" hose which maintains a constant flowthrough orifice, thus preventing the accumulation of the animal's excretion.

In addition, a valve was designed to prevent the return flow of urine to the body of the animal. The rubbing edges of the clothing were softened with special "paralon" edging. Thus new improvements were gradually introduced during the course of the experiments.

Now let us return to the case involving Chizhik. Having failed to solve the mystery of his disappearance, the scientists decided not to

experiment and returned to their tasks. After an hour, however, additional news: Chizhik has been found. And indeed, in looking through the observation window you would see Chizhik's excited pointed snout behind Irma's back. Now we know where he has been hiding. It seems that he came over to Irma's side by making a hole in the rear part of the screen separating the capsule into two parts; here he hid behind the back of his partner. But it is still not clear how he managed to escape the restraint clothing.

At the end of the experiment the scientists found Chizhik's sanitation-restraint suit on the floor. All of the straps and tethers are intact, with only the edge of the suit torn around the neck. Now it becomes clear: the dog simply crawled out of its attire, much like, for example, a crab crawls out of its shell.

How could this happen? It turns out that the suit was not properly fitted. All of the animals differ in build, not to speak of size. As a result, even properly made clothing must be resewn and tightened each time it is put on. In other words, not only must the suit be sewn by a master tailor, but it must be sewn for the "individual" as well. In this case this rule was not observed with sufficient care, and you have seen the result.

There is yet another circumstance that is of great significance: the animal must gradually be trained to exist under the conditions of the experiment while dressed in its sanitation-restraint suit. An untrained dog is ill at ease, and tears and pulls at the chains. This is understandable: confinement is particularly difficult to take when one is unaccustomed to it, and this applies all the more so under the sealed conditions that prevail in the capsule, where no man is permitted to approach the dog for a long period of time. Again, this part of Chizhik's training was neglected.

In addition to the sanitation-restraint suit, some of the animals have been provided with additional clothing, designed to prevent damage to the electrodes by means of which the physiological functions of a given dog are recorded. We will have more to say about this particular type of clothing later on.

The dogs grow accustomed to "being dressed" all the time. They also become used to the procedure of dressing and fitting the clothes. It is quite interesting to see how they assume various positions and execute a number of movements in order to assist in the completion of this process.

The insides of the legs and other particularly sensitive portions of the dog's skin are covered freely with a thick cool mixture of vaseline and a penicillin ointment; (the free application of this salve reduces chaffing by the clothing, and if sores should develop the ointment will prevent the development of infection). And the dog seems to understand this. It doesn't resist at all. You need only try to place the collar of a shirt over Lisichka's snout, and she moves her head immediately in the direction of the shirt. The dog obediently then raises her paw which is passed through the "sleeve." It is quite amusing to see how the animal obediently freezes into a motionless position, folding her paws, thus making it possible to stitch a neat seam with caprone strips about the belly.

Now everything is complete: the dog rises and, of course, the first thing that the animal does, is to shake itself. Then the tail begins to "work" most energetically. Lisichka attempts to lick the hands of the person working with her, seeking to be petted. And the animal's appearance shows clearly that it is not suffering in this seemingly unnatural form of clothing for dogs.

TRAINING

We find Marsianka - a small smooth dog with a round head - in a capsule that is barely larger than the dog itself. Her rapid breathing causes her chest, confined by the clothing, to heave. Her rate of breathing is 69 per minute. The normal rate should be 26-30. The dog's mouth is slightly open, she drags herself out of the capsule and refuses to eat. The laboratory assistant measures the animal's temperature and obtains a reading of 40.2° , which is substantially higher than normal.

This is one of the procedures involved in training these future small astronauts to exist in the capsule. This "training" is not identical for all, nor is it easy for all of the dogs: many of the dogs find this a torturous process.

It is absolutely necessary to train the dogs to be able to spend a long period of time in a single position, virtually without movement, yet at the same time feeling normally well; unless this condition is satisfied the extensive experiments cannot be started.

The situation is the following. Many important ground experiments, preparing for the flights into outer space, as well as the overwhelming majority of these flights themselves take place within the surroundings of a small hermetically sealed capsule. During the course of the experiments no man can approach any of the animals for long periods of time, nor can any steps be taken to improve the animal's condition. This is the reason why scientists must work with dogs which can spend considerable periods of time under the conditions prevailing in a small capsule without the danger of any pathological changes. However, the normal vital activities of these experimental dogs, under the conditions that prevail during the experiments, can be achieved only through extensive training.

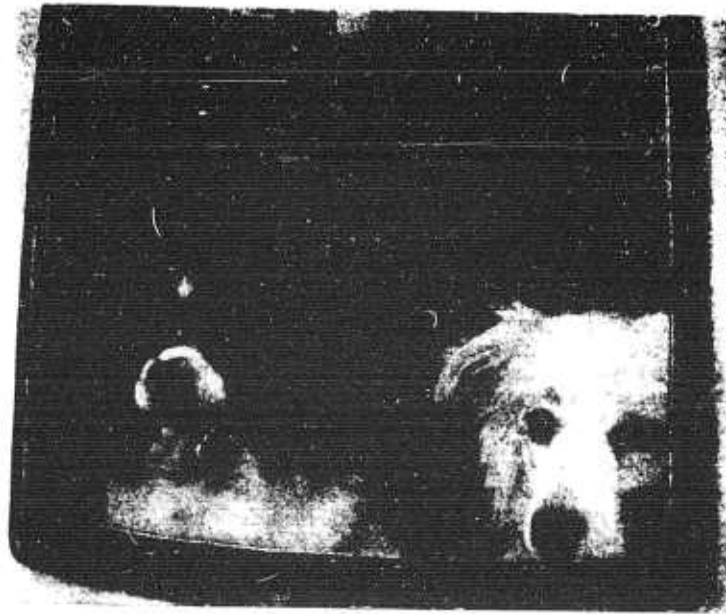
Everyone is familiar with the fact that the dogs are extremely active and mobile. The dogs observe carefully everything that is happening around them, they sniff, they run, and they bark - their behavior is varied and changeable. Animals such as these must now be confined in a chamber, depriving them of all opportunity to move and execute similar intense movements.

Moreover, the dogs must be trained to carry out all of their natural functions in a rubber suit, without moving off a particular spot. This is also quite difficult. After all, the act of excreting urine and fecal matter has, during the lives of millions of generations, been associated by these animals with free movement and particular positions.

At first glance it would seem almost impossible to train dogs to function in the above manner. How is one to reconstruct the behavior of animals to such an extent that they easily and simply execute all of their natural functions within the confines of this special form of clothing? Can the instincts of animals be changed to such an extent?

The answer to this question was obtained as a result of the experience gained in working with dogs.

In contrast to the practices of scientists abroad, who initially, as a rule, employed anesthetized monkeys as their experimental subjects (and these were, moreover, rigidly restrained), Soviet space medicine from the very beginning set itself the goal of using dogs that were active and awake rather than anesthetized, and these animals were to be employed in their normal state of health, under conditions which did not call for rigid restraint. Hence the problems of animal training and the imposition of rigorous requirements on this process assumed particularly great significance. The principles and programs for the training of dogs to behave quietly in a small capsule for periods of approximately twenty days were developed and theoretically validated.



The training of dogs in a section of the capsule.

Let us describe, by stages, all of the training measures that have been implemented.

First of all we have to select those animals which can be trained most easily to remain quiet for some period of time, i.e., without intense movement. This selection procedure makes it possible immediately to reject those dogs which cannot sit quietly in one spot for long periods of time. But this is not as simple as it sounds; it is not always possible to arrive at a conclusion regarding the suitability of animals for such experiments on the basis of information obtained through the observation of the conventional behavior of these animals. There have been cases in which extremely quiet and gentle dogs, on entering the capsule, behaved violently and could not be quieted.

The dogs are trained for their stay in the capsule in a special room which has been designated as the "training room." This is a light

room with a cement floor, wide wooden benches, and small sections of carpeting placed over special heated portions of the floor. Despite the ozonizers attached to the walls and even though flowers have been placed on the wide marble window sills, the room smells of animals. You have but to open the door, and you will be greeted with the "happy" barking of the dogs.

There are many dogs here, but you will not notice them immediately because they lead an unusual form of life here and are kept within a variety of chambers and compartments. You are immediately struck by the special capsules that have been set up on high metallic supports. Set up on the left side of the room, they have the appearance of long-legged beings without bodies. Then there is the even stranger "cyclops" chamber, i.e., a chamber whose shell contains only a single "eye" - the observation window. The purpose of this device is to train the dogs to exist under conditions of poor illumination. There are one or two dogs in each such capsule.

We can see some more animals on a wide bench. We find them lying here in special compartments. As you approach, the dogs begin to wag their tails, and they extend their snouts. These animals are being trained to spend some time in these compartments.

To the right you can hear whining and howling, but it is difficult to ascertain where these sounds are coming from. There a number of unusual and narrow cells positioned on short legs along the wall of the room, beneath a large portrait of Layka. These are the so-called "tight cells" intended for the first stage of training; they are made of aluminum alloys and are perforated with many round orifices, each the size of a small saucer. If you look closely you will see the black nose of a dog sticking out of one of these little windows. This is the source of the persistent whining.

The confinement in this tight cell is the first stage in subduing the efforts of the animal to execute intense movements. Dogs confined in this manner cannot walk around because the "tight" cell is very much smaller than their usual enclosures, but they can turn in various directions. Thus the tight cell represents a restriction of their accustomed domicile, but not to the dimensions of the actual capsules in which the animals will be deprived entirely of the ability even to turn around.

As a rule, when the dogs are first placed in this tight cell they "protest" actively against this restriction of their freedom: they bark, they whine, and they scratch the floor. We see that some of the dogs push against the movable walls - in effect, doors - thus managing to open the cage and jump out.

In a cell encircled by several strands of wire we find the dog Knopka. These wires alone interfered with the "initiative" of the animal, that had quickly mastered the habit of opening the door, to jump out of the cell for a fifth time. Now Knopka sits quietly, apparently understanding that there is no point in wasting energy unnecessarily. We can see her nose, held quietly in the round orifice - the little window - and her black eyes glisten like beads.

Dogs "kept" for one to three days in this tight cell are given a chance to rest, and then they are dressed in the restraining suit and placed in a capsule, where they are leashed to the walls of the capsule by means of the special rings on the clothing, described above. This capsule is not hermetically sealed, and it is possible to approach the dog at will.

Now begins the second stage of the training - the period of so-called partial fixation. The animals can no longer turn around in the capsule, but they can move forward, backward, and 10-15 cm to the sides.

The dogs do not take well to such enforced captivity if it is prolonged from the very beginning. Therefore, at the beginning, a 7-10 hour stay on the part of an animal in the chamber will be interrupted by walks in the yard, giving the dogs an opportunity to loosen up. We should stress the fact that during these walks the dogs do indeed run and play more than is usual.

How do the animals behave in the capsule?

Whenever Lepeshka - a yellow-rust colored dog with short legs - is tied down, she lies down quietly on the heated floor. She sits and looks around her or she starts to doze with her eyes closed. As other dogs approach the chamber, you hear a warning growl. As the experimenter or his laboratory assistant approach - Lepeshka rises, shakes herself "busily" from head to foot, slowly wags her tail, "shows interest," and quietly looks into the bowl which contains a warm and fragrant meal of meat. All of this dog's reactions are amazingly normal. It would seem as if she had been in the capsule for a long time and feels at home. The behavior of this dog instills us with the confidence that she will prove to be an excellent animal for the experiments. This prediction will be borne out.

Dinga, a lanky white dog with sad, dark, and resigned eyes, behaves differently. When placed in the cell she does not at first "want" to lie down, i.e., stubbornly she continues to stand. From time to time the animal whines "longingly." No special techniques are required in order to come to the conclusion that this particular dog has a far more difficult time in overcoming her loss of freedom.

On the other hand, when Denek is fastened into a chamber of this type, she behaves unusually sluggishly. This healthy dog lies down the entire time. When the experimenter approaches Denek, the dog barely raises her head before she again droops down onto her paws. She just

lies there, taking no part whatsoever, even when someone starts to undo the hooks from the chain.

Now in the chamber we find a tousled black dog with a yellow spot on her chest and little spots above her brows. At a distance, against the light background of the wall and the capsule she looks like a black inkspot. Hence her name - Klyaksa [Inkspot]. This gentle animal stretches toward the experimenter, follows him with her eyes, and tries to lick his hands. Klyaksa's entire behavior, it would seem, cannot be regarded as a foreboding of anything wrong. It is a pleasure to deal with such a good dog; apparently, there is no reason to anticipate anything unfavorable or unexpected.

After fastening the last chain clamp onto the dog, we leave the laboratory, closing the door behind us; but we can keep the animal under observation through a special window. However, the dog has now been left to its own devices. Klyaksa looks around. She gets up, she sits down, and she pulls at the chains until she has no more strength left. However, the chains do not let go and exert considerable pressure on the animal. The dog moves its entire body back and again is subjected to pressure. This makes the dog even wilder: she begins to strain at her chains and leans her paws against the screen. The resistance stimulates her. The animal's movements become more rapid and frenzied.

On the morning of the following day we find that the dog has completely mutilated the capsule. We can only express surprise at the fact that such a small animal has been able to damage such a thick wire screen within a comparatively short period of time: the screen is pushed in on one side, torn on the other, and the edge bent up. Tremendous strength is required in order to accomplish this.

And what of Klyaksa? As before, Klyaksa greets us very happily and

fawns on us, as if nothing had happened. What amazing transitions from violent activity to complete quiet. There is no choice but to conclude that all of the destruction caused by Klyaksa was a result not of her hysterics, but rather a result of her quiet but active protest against the loss of her freedom.

The experimental dogs exhibit a variety of peculiarities in connection with their nervous systems. The success of the work with the animals depends on these peculiarities and on the manner in which the dogs have been trained.

The numerous experiments conducted by the genius Russian physiologist, I.P. Pavlov, and his coworkers have demonstrated that nervous activity is determined by two processes: stimulation and inhibition. These processes, in turn, are characterized by a number of properties the most important of which are the strength of the stimulation and inhibition processes, balance, and mobility. These properties can be present in the dogs in various combinations.

Animals whose nervous systems exhibit great strength, balance, and mobility, quickly and easily adapt to the changes produced by the conditions of the experiment, they withstand well any deprivation, and they are less subject to disruption of the higher nervous activity.

However, problems arise if the adaptation of an active dog to its new conditions follows an undesirable course. In such cases we find such excesses as were seen with the tireless Klyaksa which could not be pacified. Such behavior, however, is encountered relatively rarely. More frequently, those animals exhibiting strong nervous processes are able to withstand well any changes in the circumstances of their life, and their higher nervous activity is not disrupted.

We do, however, encounter a great variety in the behavior of the animals. Some of the dogs exhibit extremely strong stimulation pro-

cesses, whereas in others the stimulation is expressed in weaker form. For example, if Veterok - a little black dog with a wide back - loses her "self-control" and begins to run around in circles, move, strain, or even worse, if she begins to gnaw at various items in the capsule, nothing can be done to calm her. Neither threats nor punishment have any effect on her.

Il'va, on the other hand, shows pronounced inhibitory characteristics. She can remain motionless for long periods of time and it sometimes seems as if she has no need to move at all.

With Pugovitsa it was enough twice to shake a finger and once to raise a hand at her to bring an end, once and for all, to the whining in the chamber. This reaction was inhibited in her, and done so rapidly. In order to achieve the same with Dinga much work and time was required; in this dog the inhibitory reactions develop slowly and gradually.

The process of stimulation which acts on a particular portion of the cerebral cortex may be replaced by an inhibitory process, and vice versa. This property of the basic nervous processes was designated as "mobility" by I.P. Pavlov, and this term now exists in scientific literature.

There is yet another property of nervous phenomena which has been defined by I.P. Pavlov as basic. This is the relationship between the stimulation and inhibition processes. In certain animals these processes offset each other, whereas in others the inhibitory processes predominate; in a third group of animals, on the other hand, the stimulation process may be predominant. Let us remember, for example, how "reasonably" such an animal as Lepeshka behaves: this animal does not waste energy unnecessarily, does not fuss in the capsule, yet at the same time she does not surrender her capacity to execute all possible

movements (she changes position, and reacts actively to her surroundings).

Zhemchuzhnaya, Lisichka, Umnitsa, Strelka, Snezhinka, and Belka behaved in the same manner. At one time Layka also behaved this way. Dogs in whose nervous systems the stimulation and inhibition processes are not balanced in this manner either show a disruption of the stimulation reactions or they become extremely sluggish, like Denek, for example, in whose nervous system the inhibitory processes clearly predominate.

Everything that we have said pertains to animals with strong nervous systems.

A dog with a weak unstable nervous system will not be able to withstand any pronounced change in its living conditions, i.e., restriction of freedom or even mobility. If stimulation predominates over inhibition, their reactions will become unrestrained in nature.

The dog Zhuchka, for example, also behaved in an unforgivable fashion; one can see marks left by her teeth where she bit into the wooden sections of the chamber, her clothing was torn, and the wires have been gnawed through. But this dog is different from Klyaksa; Zhuchka continues to strain at her leashes, to the point of actually hurting herself. Zhuchka's movements are carried out "without reason." Her breathing is shallow and rapid, and her mouth is constantly open. The dog reacts only to extremely strong stimuli; here her unrestrained activity is replaced by unusual immobility, i.e., she literally "holds her breath." The animal refuses to eat and everything points to the fact that there is something wrong with Zhuchka's nervous system.

Irma, a little white fluffy dog with black spots, exhibits behavioral patterns that differ from the norm, but are not clearly expressed. These patterns do not disappear during the course of the training, as

is the case with other dogs, but conversely, they become more pronounced. The scientific workers were "dumbfounded" for a long time by this dog, but she finally had to be rejected, as was Zhuchka.

The study conducted by I.P. Pavlov on the higher nervous activity of animals allows us to relate the behavior of dogs during their training with certain features of their higher nervous activity and it also makes it possible for us to determine the particular type that is best suited for the conditions of the experiment. At the present time it is recognized that it is absolutely mandatory to select dogs with strong motor and balanced types of higher nervous activity for flights into outer space.

During the initial training period, i.e., during the period of partial fixation when the animals are first forced to spend many hours in an immobile position, the features of their behavior, and the type of their higher nervous activity come to the fore most vividly. And this should not be surprising. The dogs find, on having been placed inside the capsule, that they are in a difficult situation; however, not yet trained, they express most clearly those of their individual characteristics that have not yet been suppressed. In this respect, the stage of partial fixation for the dogs is extremely indicative. After all, later on so many changes associated with the training and the development of various habits will be superposed on the behavior of the animals. Distorting and thinly disguising the initial behavior of the animals, such habits make it extremely complicated to determine the type of higher nervous activity during the course of the subsequent work. It is for this reason that it is extremely important to evaluate the quality of the nervous system during the partial fixation of the animals.

We can state in advance that Lepeshka, quiet, but by no means in-

hibited, will be an outstanding astronaut. Lisichka, Metel', Strelka, Knopka, and Belka, all animals with a balanced nervous system, were evaluated similarly. Dinga, Planeta, Kapel'ka, and V'yuga, all oversensitive to partial fixation, cannot be graded higher than a "three." A number of the dogs, so as not to waste time unnecessarily, should be rejected immediately.

With the partial-fixation experiments described above, the second stage of the training program comes to a close. The animals are now given a chance to rest. What tests await the dogs in the third stage?

The animals are carefully dressed in their rubber sanitation-restraint clothing. They are then set on the floor and "invited" to take a walk. At first, in this unusual type of clothing, the animals cannot run confidently, and this is shown by the fact that they spread their paws wide, but after a certain interval of time they rapidly grow accustomed to the new form of clothing. At this point the behavior of the animals does not in any way differ from normal behavior.

After the walk the animals are fastened into the capsule for many days. It is at this point that the third training period begins.

The dogs have now been sitting in the capsule, and wearing their sanitation clothing, for several days. Let us take a look at Volna. Her breathing is shallow and labored. The dog's mouth is open. Sometimes Volna whines complainingly, she frequently crosses her paws, tries to get out of the capsule, and her reactions indicate annoyance at external stimuli (sounds, the appearance of people, other dogs, etc.). The dog refuses to eat.

Il'va is in the next compartment. Like a well-made plush little toy, she lies quietly and only the excited movement of her eyes tells us that this dog is living under great tension. Il'va's mouth is shut tightly, but her breathing rate is also in excess of the norm.

On the other hand, in Zhemchuzhnaya's behavior there are no apparent changes, her body temperature is normal, and the breathing rate and electrocardiogram are also normal. As before, the dog is happy, gentle, and looks about her with interest. She does not move excessively, but at the same time she frequently changes position, i.e., first she sits, then she gets up. The instant that people appear, she immediately turns in their direction and wags her tail.

The overwhelming majority of animals, placed for the first time into the capsule while wearing their sanitation clothing, do not feel very well after having spent ten or more hours there. Certain of the animals execute intense disordered movement, whereas others lapse into immobility. Many of the animals in this case become noisy, howl, whine, and wail. All of these represent various aspects of their relatively serious condition, which arises despite the fact that they had been trained to spend long periods of time within the capsule.

Then there comes the time at which the condition of the animals and their behavior show pronounced improvement. Later on, however, after 10-12 hours, the same situation as before, although now in a much less pronounced form. Everything is repeated. Gradually the condition and behavior of the dogs return to normal.

How can all of these phenomena and the strange quantitative relationship between their onset and disappearance be explained?

Let us turn our attention to such seemingly prosaic items as the sanitation tanks in the capsules in which the dogs sit. For purposes of the experiment these tanks have been replaced with glass columns making it possible to record exactly when and in what quantities the dogs urinate.

Within 5 hours after Zhemchuzhnaya was placed into the chamber, there were some 60 g of urine in this glass column. After an additional

hour and a half there were another 35 g, etc. In the glass columns attached to the chambers in which Volna and Il'va are sitting, there are no liquids at all. This means that the urination of these dogs has been inhibited, and for almost an entire day at that. This can serve as an explanation of the abnormal forms of behavior. After the animals excrete urine and fecal matter, their condition immediately improves.

Gradually all of the dogs begin to carry out the functions of defecation and urination regularly, despite the unaccustomed clothing and position.

Those dogs which, like Zhemchuzhnaya, quickly make the transition to a normal rhythm of excretion under unusual conditions withstand their stay in the capsule easily. The goal has been attained. The animals trained in their sanitation-restraint clothing can spend considerable time in the capsule and actually gain weight.

Lisichka is our very favorite. In this dog we have somehow found a combination of those properties which are generally not found in conjunction with one another: she is obedient, she exhibits "initiative," and moreover she is very cheerful and buoyant. She is quite active and attentive during the experiments, while at the same time her behavior exhibits no excessive activity, and this is borne out by the fact that she did not once gnaw at the sensing elements and instrumentation. As one first familiarizes himself with all of the remarkable properties of this animal and with its behavior during the experiment, it seems as if nature had created Lisichka especially for scientific experimentation. But Lisichka is only in part a creation of nature: a tremendous role in the development of good experimental animals is played by the patient, loving, and thoughtful attitude displayed by the investigators in the training of the dogs.

AN AUTOMATIC DEVICE FOR FEEDING

During a flight the dogs will have to be fed without being able to avail themselves of human assistance. A special automatic device has, therefore, been developed for this type of feeding procedure. As a result, however, the animals must be trained not only to function normally during an extended stay in a small capsule, to wear clothes, etc., but they must, in addition, be trained to take food from this automatic device.

Imagine a clothed and firmly fastened dog in a capsule, the dog lying in its normal position (its paws extended forward); in front of the dog there is an opening in the floor through which we can see one of the containers of the food automat.

The automat is in the shape of a box, and is installed beneath the floor of the capsule. Essentially, this automatic device is a conveyor belt with sockets into which special boxes filled with food are placed. The belt does not move continuously, but rather intermittently. Each of the boxes opens up as it moves into position, i.e., to the point at which there is a special hatch in front of the dog's paws. The switching-on of the automatic device and the opening of the covers are accompanied by characteristic sounds.

In order for the dog to begin to eat and consume completely all of the food prepared, she must be trained to the shape of the automat, the noise it makes, the loud click which is heard when the box covers are opened, etc., and she must learn to take the food from the lower tapered portion of the box and then - and this is even more difficult - from the very bottom.

In connection with the fact that the feeding process will take place under conditions of weightlessness, there arose the question as to the type of food to be employed. Imagine the following. A space

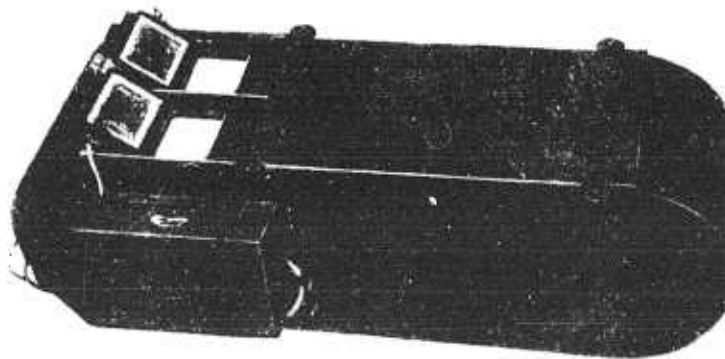
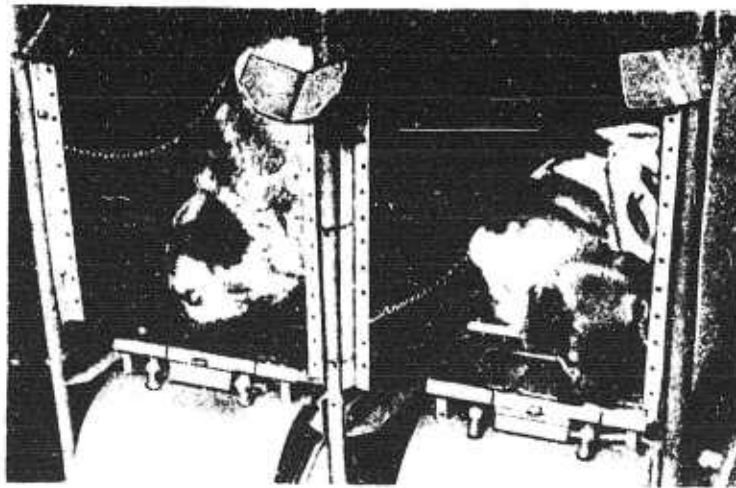
vehicle in orbit, and all things have lost their weight. It is now time for the animal to take its food.

Let us assume that this food consists of slices of sausage. As the animal lifts the cover of the feeding device we will find an interesting situation. A slice of sausage, under the impetus of the jolt produced as the automatic device comes to a stop, seems to rise, like in a fairytale, to the snout of the animal: all that remains to be done here is for the dog to open her mouth and catch the slice of sausage in flight. If the dog succeeds in doing this, the slice will be eaten, but what will happen if she fails to catch the slice of sausage in flight? Imagine that she did not manage to catch the food that had been prepared for her or that the food broke up into several pieces. Now these pieces are flying in all directions and the food is inaccessible to the animal.

Water also "behaves" unusually under conditions of weightlessness. As the dog attempts to lick it, the water does not reach her mouth but rather, separating into small globules, it spreads out in various directions. No matter what attempts the animal makes to drink the water, under conditions of weightlessness it is virtually impossible to drink water from an open container.

All of this increases the difficulties encountered in the feeding of the animals and providing them with the required quantities of water; these are difficulties which arise in flights aboard an artificial satellite. What is to be done?

Obviously the animal must be offered its food in such consistency and in such a manner as to prevent its floating away from the feeding device. In other words, the food must be securely fastened to the wall of the little boxes on the automatic feeding device. In this case, it is to be hoped that the food will remain in the automatic feeding device



The automatic feeding device.
under conditions of weightlessness.

And how about water? It is impossible to let the dog remain without water. However, a solution was found.

A special high-calorie content mixture was prepared; this mixture, in addition to sausage, meat, fat, and millet, also contained a large quantity of water. This mixture is a viscous jelly-like mass of which water is a component part. Since it is structurally linked to the various food products, the water can no longer pour out of the open

container under conditions of weightlessness.

A method, very similar to this clever method, was used successfully by Soviet scientists in the launching of the second satellite, in 1957, with Layka aboard; this method eliminated many of the complex and, at first glance, insoluble problems involved in the feeding of dogs under conditions of space flight. Later on, in 1960, Belka and Strelka were fed such a mixture aboard the second satellite space vehicle.

How then are the animals trained to make use of this automatic feeding device?

This can be done simply; place the animals into a capsule, in front of the automatic feeding device, and wait until they have become extremely hungry; they will take the food. However, there are complications that arise in this case that are extremely difficult to predict. Once the animal has overcome its "fear" of this unusual feeding device, it will at best lick the upper layer of the food and then refuse to eat anything at all.

At first the reason for this behavior was not clear. As far as taste was concerned, this dog food was excellent. Dogs outside of the capsule would eat this food instantaneously, as if it were a delicacy. They eat this food mixture almost as quickly, outside of the capsule, when it is offered in the unusual boxes of the automatic feeding device.

This indicates that the problem lies not in the food itself nor in the manner in which it is offered. What, then, is the matter?

Let us go up to the capsule in which the dog is seated. The box of the automatic feeding device is open. The animal is clearly excited. It is standing, and impatiently moving its paws. We direct its attention to the food. The dog reaches out trustingly for the hands of the man, and seeks to lick them. If he were now to place the food in the

palm of his hand, the dog would lick it off. One third of all of the food is thus fed to the dog, and we leave. When we again visit the experimental animal after a lapse of 2-4 hours, the food has almost entirely been eaten.

It has been established in the course of many experiments that initially the animals reject the tasty food because they want to drink. Their thirst is intensified, since by refusing to touch the food they simultaneously lose the opportunity of consuming the water which, as has already been stated, is a component part of the food. This increase in the organism's need for water generates, as a matter of course, a negative attitude on the part of the dogs to the food, thus resulting in a vicious circle of circumstances. If, however, the dog is forced to eat this jelly-like food, it simultaneously absorbs the water contained in the food and, having satisfied at least partially its sensation of thirst, the dog begins to eat. This is reason why it is extremely important to provide the animals with a sufficient quantity of water before they are placed in the capsule for purposes of training them to take food from the automatic feeding device.

It is interesting to observe the gradual change in the attitude of the dogs to water, as their consumption of the food mixture increases. Initially, when the animals eat very little, the simple action of a human being approaching the water tap will induce in the animal the most violent of reactions. The dogs keep their eyes glued on the man and observe all of his actions, and they do not cease any of their excited movements; as the water begins to flow, many of the animals begin to lick their lips and howl. And conversely, as the animals begin systematically to eat their portions of food, they become more and more indifferent to water. All of this indicates that this combined food mixture satisfies an animal's daily requirement of water.

The nutritional qualities of the mixture can also be characterized as excellent, since given this food ration the dogs, as a rule, gain weight.

It is interesting to observe how the dogs gradually grow accustomed to the use of the automatic feeding device. Initially, the animals are frightened by the rising and howling sound made by this device. They begin to strain, and glance around them in terror. Spotting the movement of the cover, they draw up their legs. Seconds pass, the noise does not abate, but no harm befalls the dogs. The animals become somewhat quieter. Suddenly there is a sharp click and the cover opens. Now the animals detect the glistening smooth surface of food before them. A long time goes by before the dogs, still frightened by the noise, begin to move or make any attempt to sniff at the food, not to speak of eating it.

Gradually, however, the animals become less and less frightened, from training session to training session, of the noise made by the operating automatic device. Now these noises produce orienting reactions in the dogs more quickly, and after additional time, the noises produce typical reactions to food: barely having heard the familiar noise, the animals hurriedly withdraw their forelegs in order not to get in the way of the opening cover, and they follow the box with the food. Many of the dogs wag their tails and lick their lips now. The instant the cover opens the dog begins busily to eat.

It is no less interesting to observe how the animals are trained to eat all of their food in its entirety. It is easy to reach only that portion of the food which is contained in the upper third of the box. Here some of the dogs lick off the soft jelly-like mass as if it were a liquid; other dogs, whose snouts are so narrow that they can open their mouths within the confines of this small box, grab the food mix-

ture with their teeth. However, to go any further becomes more difficult, since the box tapers. Now it is no longer possible to grasp the food with the teeth, nor is it possible to lick it off, as is usual: the dogs must now stick out their tongues very far, and they must push their snouts deep into the box.

But after a lapse of five to six days all of the dogs know how quickly and easily to use the automatic feeding device.

RECORDING OF PHYSIOLOGICAL FUNCTIONS

Thus the animals have now been trained to exist in conjunction with certain of the features encountered in their experimental life. However, in flight the dogs will be subject to the action of a number of new specific factors that, of necessity, must arise in the motion of space vehicles. The dogs must "be familiarized" with these disturbances in advance and each individual animal must be examined from the standpoint of how it reacts to these disturbances. Only after this type of an examination has been completed will it be possible, in final terms, to resolve the problem as to the suitability of a given dog for flight.

Before proceeding to the discussion of this material, we must dwell in some detail on certain of the questions associated with the recording of individual physiological indices.

In actual fact, in order to arrive at a conclusion regarding the state of an animal's organism during the time it is being affected by various factors attributable to the external medium, we must stop and record on photographic film (or on special paper) the functioning of the heart, blood pressure, the nature of the respiration, etc. -- the so-called autonomic functions.

It should be pointed out that the concepts of "prior to," "during," and "after" the experiment are extremely significant in scientific

practice. These concepts denote the period in which data characterizing a given function of an organism are obtained.

The materials obtained "prior to" the experiment are collected before the disturbances take effect and characterize the initial levels of functioning for specific systems of a given animal. The materials obtained "during" the experiment characterize those processes which take place at the instant that a particular disturbance takes effect. And, finally, the data obtained "after" the experiment indicate the extent to which certain factors exert influence on the condition of the animals. In order to study in greater detail the consequences of various factors, the observations may be carried out periodically. As a result, it becomes possible in an analysis to trace both direct as well as indirect results produced by the action of the flight factors.

A number of investigations take into consideration data only "prior to" and "after" the experiment. This is understandable; it is difficult, and sometimes even impossible, to determine many of the manifestations during the period of flight or during other powerful disturbances. For example, there can be no point to an attempt to induce complex activity in a dog during a period of great acceleration. However, it is extremely important to observe carefully how the accustomed activity - conditioned reflexes - are restored after the action of high G-forces. The nature of this process may be indicative of the force and extent of the shock experienced by the animals.

The development of methods for the recording of specific physiological functions in animals under conditions of a laboratory experiment on the ground and particularly under conditions of space flight required much effort and time. We examine these methods below.

Respiration

The nature and rate of respiration have been significant indicators of the state of an organism since time immemorial.

In the case of dogs a change in respiration represents a response to various disturbances. Changes in respiration may reflect various unfavorable influences, whether prolonged, or of short duration. For example, dogs need only be stimulated slightly, and their breathing immediately becomes more rapid (the norm is 12-28 breathing movements per minute). Persistent changes in natural breathing can be observed with an increase in air temperature and humidity, in the case of "oxygen starvation" (anoxia) of the organism, etc. A speeding up of the respiration rate to 200-300 breathing movements per minute indicates that the animal is not well. A state of illness in the dogs can also be deduced from a significant reduction in the frequency of breathing movements (down to 3-1). The timely determination of the frequency and nature of respiration makes it possible to take the required steps in sufficient time to prevent any unfavorable effects. This forced the scientific coworkers to seek out various methods of recording the breathing of the dogs.

It is easy to record breathing. There are many methods by means of which this can be accomplished. The majority of these methods call for the utilization of a special device that is installed in the stream of exhaled air. Such a device must be situated somewhere in the vicinity of the mouth. Experiments have shown that the dogs rapidly become accustomed to sitting quietly in such a mask. It would seem that everything now would be simple and in good order.

But now there arises what appears, at first glance, to be an insignificant, yet in actual fact, an insurmountable obstacle. The mask interferes with the feeding of the dogs and for this reason alone must

be removed in the case of extensive experiments.

On closer examination other generally accepted methods for the recording of breathing prove to be unsuitable.

What is the solution? How are we really to record the breathing of the experimental animals? Scientific workers, in conjunction with engineers, repeatedly returned to the problem of the "objective" monitoring of the respiration of the dogs. As a result there appeared the so-called breathing sensor. The word "sensor" has only come into scientific usage recently. This is a device which is fastened to the animal or in the capsule and reacts to changes in any physiological or physical phenomena such as temperature, electrical resistance, motion, etc.

The so-called contact respiration sensor was originally designed as a belt that is worn around the chest by the animal. With each intake of air, as the air enters the lungs, the perimeter of the dog's chest increases by approximately 7-10 mm. This produces a change in the degree of tension exerted on the sensor that is attached to the chest of the animal, and as a result the contacts of the sensing elements in the sensor close.

Other methods have also been developed for the recording of the frequency of respiratory movements. Imagine a carbon layer applied to the surface of a rubber tape. Even if the tape is stretched only slightly, the carbon layer will alter its electrical resistance. During the process of recording the breathing, a weak electric current is passed through. As this elastic belt is stretched the resistance of the carbon layer changes, and this resistance is recorded by means of special devices. This is the operating principle of the so-called carbon respiration sensor.

The carbon sensor is produced in yet another version: it consists, for example, of two rubber tubes, filled with carbon powder, and capped

with bronze tips. As the tubes are stretched during inhalation, their lateral cross section is reduced and, consequently, the thickness of the carbon powder and the resistance of the carbon powder are both reduced. It now remains only to record the resistance of the sensor, and it will thus be possible to arrive at a conclusion regarding the frequency of breathing.

The rheostat respiration sensor is designed in accordance with another principle. Its main part is a small circular rheostat with a moving slide. As the animal takes in air - and the perimeter of its chest increases - the cable that is belted about the dog shifts the slide of the rheostat, thus also producing a change in electrical resistance.

The respiration sensors were constantly improved and changed in external appearance. Initially, they were similar to a gunbelt, then to a rubber belt with a narrow edge of piping, and finally they resembled a thin quilted jacket. Now these sensors have been incorporated in the protective clothing made of non-shiny caprone fiber, gathered into fine pleats. At the sides there is a special cable that passes through liners designed to prevent the parting of the cable and through a transparent Plexiglas tube.

The animals quickly become accustomed to this unique form of belt and can wear them for long periods of time, as if nothing were happening. Almost any experiment involves the simultaneous recording of the animal's breathing. The respiration sensor is fastened beneath the sanitation clothing in the case of experiments involving many days; in the case of relatively short experiments, the sensor is placed beneath the restraint clothing.

The dog is sitting in the capsule. It seems that its chest is not moving at all. However, the sensitive stylus connected to the contact

sensor moves and draws a small but neatly outlined peak on the tape of the device. The number of such stylus peaks per minute is approximately constant: 22-25. This means that the dog is breathing and is drawing 23 breaths per minute.

But now we see that the breathing rate rises somewhat - 32 respiratory cycles per minute; after a bit more time has elapsed the respiration rate increases to 41, and subsequently to 56. And now we begin our regular monitoring of the experimental conditions by referring to the instruments; what is the temperature in the capsule, is the dog being adequately supplied with oxygen, what is the dog's pulse rate, etc.? The undesirable factor is eliminated and the investigator records, with satisfaction, a drop in the respiratory rate for the experimental animal.

Arterial pressure.

Blood pressure has, since time immemorial, served medicine as an important indicator of a change in the activity of the cardiovascular system and this pressure also makes it possible to arrive at some conclusion regarding the state of the nervous regulation of physiological functions. Assume that you have scared a dog - she will press her belly to the floor and follow your actions with terror. The instrument immediately shows a rise in blood pressure. The dog begins to move, jump, and move her paws - and again there is a change in the blood pressure. This pressure changes at those instants in which the animal or a man experiences pain or when any other unfavorable factors take effect (including mechanical factors such as a blow or a shock).

What is meant by blood pressure? With which of the phenomena familiar to us can it be compared? What is the role of blood pressure and on what factors does it depend?

Any model would be a gross simplification of the actual situation

taking place within a live organism, but nevertheless it is sometimes extremely difficult not to resort to such a model in order to explain a given complex phenomenon. Place your palm beneath a weak stream of water coming out of a faucet. It flows softly and easily over the skin of your hand. This means that the pressure of the water particles in this stream is relatively low. In another case the water strikes the hand with some force, indicating that there is greater pressure.

We know that when a full container is connected to another, the water quickly tends to move into that container in which the water level is lowest and where, consequently, the water head (pressure) is lower. Thus the pressure of the liquid causes the liquid to move in this system. The pressure, in turn, depends on the diameters of the vessels (containers), the quantity of liquid, viscosity, the flow rate, etc.

This entire complex of phenomena takes place in a living organism: blood flows through vessels at a definite pressure, and this pressure changes with vessel distance from the heart.

In the aorta - the largest blood vessel - this pressure is great: here a man's blood pressure is 110-130 mm Hg. At first glance, this seems to be a paradoxical phenomenon: after all, the aorta is the largest blood vessel, and the larger the vessel, the lower the pressure within it should be. But it turns out that any reference to the size of the aorta is only relative. In actual fact this vessel, conversely, represents the narrowest point in the circulatory system. Actually, if all of the clearances in the arteries and the capillaries into which the blood flows from the aorta were combined, the clearance of the aorta would be many times smaller than that of the combined vessels.

Thus the pressure in the aorta is higher, whereas it is low in the narrow capillaries and arteries. In the capillaries it is equal to only

20-40 mm Hg. Accordingly, the flow rate of the blood through the capillaries is substantially lower. All of this is of biological significance because the exchange of gases between blood and tissues (the entry of oxygen into the tissue and the flow of carbon dioxide from the tissue to the blood) takes place precisely in the capillaries and if the flow rate here were great this process could not be carried out.

Then the capillaries again link initially to form small veins, and then larger veins through which the blood returns to the heart. Blood pressure in the veins increases with approach to the heart, and the blood flow rate again increases.

Blood is made to circulate by the contraction of the heart, muscle movement, and a number of other factors (the adhering action of the chest, etc.).

The clearance in vessels whose walls contain muscle fibers may be greater or smaller; this is regulated by the nervous system, and this also has a direct bearing on the magnitude of the blood pressure.

The situation is made immeasurably more complicated if we take into consideration that the viscosity of the blood (it is five times greater than the viscosity of water), etc., also has an effect on the blood pressure.

All of this must be taken into consideration in an attempt to explain the nature of the changes which take place in blood pressure under the action of various factors. It is absolutely necessary to know how blood pressure changes in dogs in comparison with the initial blood-pressure level, i.e., the blood-pressure readings prior to the experiment. Such data make it possible to make judgments regarding the shifts that have occurred in the cardiovascular and nervous systems, as well as the effect of the various factors under investigation on the organism.

How can the blood pressure of the dogs be measured? A number of

methods have been devised for this purpose.

The carotid artery, or perhaps some other, is cut in an anesthetized animal that is well fastened on an operating table (in order to measure the pressure in the veins, the vein must be opened). A cannula is inserted into the cut vessel (a glass tube reminiscent in shape of a tiny bottle without a bottom). A tube leads out from the "neck" of the cannula. A magnesium-sulfate solution is poured into this tube in order to prevent the blood from coagulating. The tube is connected to a mercury manometer - a device which measures pressure.

The minute the cannula is inserted the blood quickly runs into the tube and exerts pressure on the magnesium-sulfate solution, thus exerting pressure on the mercury in the manometer. The mercury rises correspondingly to the level of the blood pressure shifting slightly throughout, following all changes in blood pressure, thus indicating the pressure in a given artery. This is the so-called direct method of determining blood pressure. It is the most exact.

This method cannot be used in a flight in outer space. After all, healthy and wide awake animals, in one piece, must be sent into the cosmos.

Other methods that are similar cannot be used for the same reason. Bloodless methods of recording blood pressure are required. What is to be done?

Before us we have a dog whose expression is blank and whose behavior is unusual - she does not react to her name and, after several steps, lies down on the floor. She was given an injection of morphine several minutes before, causing the dog to become insensitive to many stimuli including pain.

The laboratory assistant places the animal on a table, strands are looped around the paws of the animal, and the open ends of these strands

are then tied to special planks in the table. The assistant opens the dog's mouth by means of a special mask. Now the animal begins to breathe ether and falls asleep. The operation begins. There is a special purpose to this operation and namely to draw out from the body of the animal one end of a large blood vessel hidden in the neck muscles - the carotid artery.

The surgeon makes two parallel incisions and opens the skin in the dog's bent neck. The dog sleeps soundly and feels nothing. Gradually separating the tissue, the surgeon draws out the carotid artery and wraps it in a piece of skin which, when sewn together, holds the artery as if in a soft tube.

Ten days have gone by since the operation. The dog has been running around the yard for a long time. This is a healthy and happy animal. We call the animal over and take a look at it. The dog becomes quiet as we pet it. We find a pencil-thick loop beneath the white neck fur that has already grown slightly. Pressing lightly against this loop and noting the sensation in our fingers, we find that there is a solid elastic blood vessel inside of the skin sack which is pulsating at 80 to 100 beats per minute. This is the carotid artery.

Now we must select a blood-pressure cuff of the required size and we have to train the dog to wear it quietly for long hours and, then, for days. The animal, with its cuff on the carotid artery, is examined each and every day in order to prevent even the slightest signs of rubbing sores or open wounds on the skin sack.

This is how the dog is readied for the recording of its blood pressure in a bloodless manner.

A small metallic cuff is placed on the carotid artery of the dog that had been operated on; within this cuff there is a small rubber "cushion." If air is forced into this "cushion," the latter expands

and presses against the carotid artery; in essence the same thing takes place when the blood pressure in a human being changes.

The pulse.

Changes in the nature of the pulse (in frequency, rhythm, pressure, etc.) were used by doctors in ancient times in order to evaluate the functioning of the heart.

It is generally believed that the pulse is associated with the movement of the blood. But in actual fact this is not so. The rhythmic fluctuations in pressure in the large blood vessels near the heart are closely related to the systole (contraction) and the diastole (relaxation) of the heart. These fluctuations are directly associated with the functioning of the heart.

During the systole 50-80 mg of blood enter the aorta. The blood expands the walls of the aorta, causing the blood to surge through the arteries [producing a wave of elastic oscillation]. These fluctuations (oscillations) are referred to as "the pulse." The speed with which the pulse oscillation is propagated by the arterial wall is substantially higher (by a factor of 5-10) than the linear flow rate of the blood in the arteries, i.e., the speed with which each drop of blood moves through the arteries. Therefore, the pulsating oscillation produced by the arterial wall occurs earlier than that portion of blood ejected by the heart during the given systole can reach the corresponding point. Thus the pulse has almost nothing to do with the flow of blood through the arteries. The pulse can be compared to a "wave of elastic oscillation" which is formed on impact, for example, against a rubber tube.

Depending on the load on the heart and the quality of the heart muscle, as well as on the condition of the valve apparatus, the nervous system, etc., the activity of the heart will also change. This has an immediate effect on the pulse. It is for this reason that the recording

of the pulse is one of the most convenient physiological indicators of the condition of an animal in space flight.

Before us we have an ink-drawn curve drawn on a long white paper tape coming out from a special instrument. This is a pulse record of the dog Strelka. The laboratory assistant measures off several centimeters on the tape and calculates the number of peaks drawn by the stylus. Knowing the rate at which the tape moves, it is quite easy to determine the pulse frequency: it turns out that Strelka's pulse is beating at a rate of 90-120 per minute. This is a normal rate for dogs.

We can judge the pulse frequency by the behavior of the stylus on the tape. If the stylus rises and falls quickly, it indicates a fast pulse. If the curve is extended, the dog's pulse is slow. The line drawn on the tape may either be steep or it may be, conversely, flat. If the peaks rise to various heights, this gives some indication as to the strength of the pulse.

Many such tapes showing the dog's pulse records at various times and under the action of various disturbances makes it possible to discuss the nature of heart activity for the given animal under various conditions, including flight.

The electrocardiogram.

An electric potential arises in the heart muscle, as in any other muscle, when it contracts - these are the so-called biopotentials for action currents. They are extremely weak - only about one ten millionth of an ampere, and their voltage is 1-2 millivolts. However, the state of contemporary engineering is such that we are able to ascertain even these insignificant electrical magnitudes. After amplification, they can set into motion the lever of a stylus, thus producing a line on a tape, i.e., a drawing.

The motion of the stylus will correspond exactly to changes in the

biopotentials, i.e., it will reflect those electrical processes which take place in the functioning muscle. Thus if two electrodes are applied to the heart muscle and these are connected to an amplifier, with the current from the amplifier led to a recording device, we can record the action currents of the heart muscle and produce a so-called electrocardiogram.

But how can we reach the heart? After all, the heart is enclosed deep within the chest.

It turns out that it is not necessary to reach the heart itself. The lines of force from an electric field, produced during heart activity, are propagated in all directions. Consequently, a difference in potentials can be detected at the surface of the body. This is precisely how an electrocardiogram record is prepared.

Each peak and interval on an electrocardiogram has a definite meaning and reflects the course of the excitatory wave through the heart. Now the atrium cordis has begun its contraction, and immediately the sensitive stylus jumps slightly upward, leaving a peak on the paper tape. After some time, the excitatory wave reaches the ventricles and the stylus immediately records this event, i.e., an entire complex of peaks appears.

Electrocardiograms were prepared for animals which had completed flights in rockets and satellites. But before good and clear records could be obtained, the researchers had much to do. Given the condition that the animal is completely isolated from the experimenter, it had to be possible to take electrocardiograms of dogs at any time during a prolonged experiment (involving tens of days). Can the electrodes provide for reliable contact during such a prolonged period of time without moving and can they remain firmly in place on the skin? After all, if this is not achieved the biological currents will not be carried to

the recording equipment.

At the moment, in order to provide for reliable contact, the electrodes are "implanted" beneath the skin of the animal. This is an easy operation which is carried out under anesthesia and is therefore painless for the dog; but the operation must be performed by "skilled" hands, or the electrodes will be "rejected."

The dog runs around in a neat green or red caftan which has a zipper running down the entire length of the back, and beneath the caftan we find a neat arrangement of wires. These wires can be connected to the equipment at any time to record an electrocardiogram.

With the passage of time, live tissue forms about the electrode (which is a foreign body) to form a connective-tissue capsule. This blocks the detection of biological currents. It is for this reason that it is absolutely necessary to implant the electrodes before a flight or a prolonged experiment. It is also important to know for how long a period of time they can function. How must the electrodes be implanted in order to have them capable of conducting the biological currents for the maximum period of time?

It was also necessary to consider the shape, thickness, and materials of the electrodes. Attempts were made to make the electrodes in the form of small saucers, small plates no thicker than a hair, ovals, and fine interlaced screens. There were many versions and tests.

And now it has, finally, become possible to obtain a high-quality record of biological currents for a period of an entire month. This was a great achievement. In individual cases, electrocardiogram records were maintained for almost two months, and once for a period of even 80 days.

Subsequently it became necessary to devise a method which did not involve the implantation of the electrodes, but rather the fastening of

the electrodes for long periods of time. Achka was the first dog on which electrodes of this type functioned for a long time. Much effort was required to prepare the glue which had to be of a quality such as not to irritate the skin of the animal; in addition, much effort was spent on the selection of the shape and the size of the electrodes and on the finding of material which would not oxidize.

The many earlier records of the biological currents of the astronaut-dog hearts made it possible to study all of the features contained in the electrocardiograms. In this manner we accumulated data which assisted us in rendering a judgment with respect to changes in the heart activity of an animal during prolonged experiments, and subsequently during flights.

Other forms of recording.

In addition to electrocardiograms, electroencephalogram records are also kept, i.e., a curve which reflects the biological-electrical phenomena taking place in an animal's brain, as well as an electromyogram, i.e., a curve which reflects the biological currents arising in various muscles of a dog, etc.

Investigations are also conducted into the changes taking place in the blood of the animals, in their marrow, in the cerebrospinal fluid, in the urine, etc. All of these detailed data are then carefully analyzed, thus making it possible to draw conclusions regarding the functioning of various systems in the organism under the action of flight factors.

It is impossible to cover all of the forms of recording. They are many and their number is growing. As new experiments are set up, various methods are being sought to determine the condition of the canine organisms.

Particularly great attention is being devoted to recording the

movements of the dogs.

A small and gentle dog named Kozyavka, fully outfitted, is sitting in the experimental capsule. Metal rings have been sewn on her restraint clothing. Two-centimeter tubes, light but strong, lead out from these rings. These are the sensing elements designed to detect motion. The dog need only move to the side of a middle line, and the slightest tension will cause the length of the sensing-element cable to change: this cable stretches as much as the animal moves. The sensors (sensing elements) have been positioned in such a manner that it is possible to render a judgment, at any given minute, regarding the position of the dog on the basis of readings shown by a special instrument.

Motion-picture and television recording.

We have spoken only of a few of the methods employed to record the physiological functions of the dogs. This data yields much and could yield even more if the various physiological parameters would be determined simultaneously with the recording of the dogs' behavior. This is a necessity both in the training of the animals for flight, as well as during the actual flight.

For example, in experiments on a centrifuge changes in the cardiovascular system are recorded, as is the respiration under the influence of acceleration. At the same time, the animal's behavior is recorded on a piece of motion-picture film. Later on, examining the records and comparing these against the behavior of the animal, it is possible to arrive at exact conclusions regarding the effect of acceleration and how the dog reacts thereto. Thus motion-picture photography has become an absolutely necessary technique in investigations.

Dogs are sent aloft in a rocket. During the flight they experience various disturbances, and the scientists on the ground can see all of

their movements. Motion-picture photography makes it possible to confirm the reliability of the various methods to shield and protect the animals, to evaluate the effect of acceleration, weightlessness, etc.

The dog is lying in a small capsule, and it seems impossible to photograph it so that its snout, its paws, and its back are visible. But several mirrors have been installed on the ceiling of the capsule and on the capsule walls. These mirrors act as "transmitters" of the various images to one another, and the motion-picture camera does not photograph the animals themselves, but rather their image in the mirror. The photographs obtained in this manner represent a maximum response to all of the requirements discussed earlier.

Still another recording method - television - was used for the first time aboard the second cosmic space vehicle. At a colossal altitude (300 km) in outer space Belka and Strelka sped headlong around the earth in their amazing orbits, and the scientists were able to see them.

A close-up of Belka appears on the television screen. Her paws seem to be slipping and sliding through the air above the capsule floor and she turns her head to the screen behind which sits Strelka; her mouth opens - the dog is barking. Strelka is seen in profile.

The utilization of television-recording methods at such great altitudes was preceded by much work: it was necessary to master the technique of obtaining good and clear images with light and small-scale equipment that required a minimum of electrical power, it was necessary to determine the optimum illumination, etc. All of these difficulties have been resolved and the method of television recording was thus advanced into the ranks of the basic methods of obtaining scientific information during the course of a flight into outer space.

Now that we have familiarized ourselves with questions relating

to the recording of physiological functions, we can turn to the description of the effect of those specific factors which the animals encounter during the main experiment, i.e., during flight. To the extent that this is possible, the dogs must be trained on the ground to withstand these disturbances and, of course, this must be accomplished in gradual stages, making the conditions of the experiments more difficult.

TRAINING OF ANIMALS TO WITHSTAND THE EFFECT OF ACCELERATION

During flight the animals will encounter an unusual phenomenon -- so-called acceleration.

Everyone is familiar with the fact that when a trolley car or bus starts up and gains speed, the passengers are pressed against the backs of their seats, i.e., they are pushed in the opposite direction. The quicker and more pronounced this motion, the greater the force exerted on the passengers.

At times this phenomenon can be expressed even more vividly. Get behind the wheel of a racing car which starts off at a very fast speed even for an automobile: within two seconds the car attains a speed of 120 km/hr. At the instant of the start an invisible hand throws you back, pressing you into the seat. Your body is filled with unaccustomed weight, and it is difficult to move or breathe.

Some people have occasion to experience the effect of great acceleration relatively frequently. This is the lot, for example, of pilots who engage in flights involving pronounced aircraft evolutions. The forces that arise as a result increase the weight of a pilot's body, force him back against his seat, bend his head, push his head down into his shoulders, and change the features of his face to a point beyond recognition.

It is amazing to observe the changes in a pilot's face, recorded on a motion-picture film, as he puts his aircraft into a sharp dive.

Frame after frame shows how his facial features become distorted, how his jaw droops, and how the position of the pupils of his eyes change. It is an unusual picture: a man's face unexpectedly acquires an unaccustomed appearance that is startling in its form.

No less astounding during this time are the sensations felt by the man. He feels as if his head is on fire, it is difficult to breathe, he feels pain in his chest and his back. And what is even worse, he loses his sight. Sometimes he may even lose consciousness. All of this happens during a particularly important instant of the flight, when each second carries with it a great many dangers. Fortunately, if this acceleration does not last for a very long time and is not excessive, the physiological functions and the pilot's well-being rapidly return to normal.

Another example shows the effect of extremely great forces. Heroic astronauts, having decided to undertake a trip to the moon, find themselves inside of a cannon in an aluminum missile. The powerful shot producing some 22 billion horsepower imparts a velocity of approximately 40,000 km/hr to the missile. The missile moves with tremendous acceleration. After several fractions of a millisecond a solid hunk of metal flies out through the muzzle. What has happened to the people? The acceleration has thrown them back against the rear wall of the missile and flattened them out.

This would have been the inevitable result for the heroes of the Jules Verne novel "Out of a Cannon to the Moon," had they not, fortunately, been imaginary. There are no devices which could have saved them from the effect of the forces of acceleration.

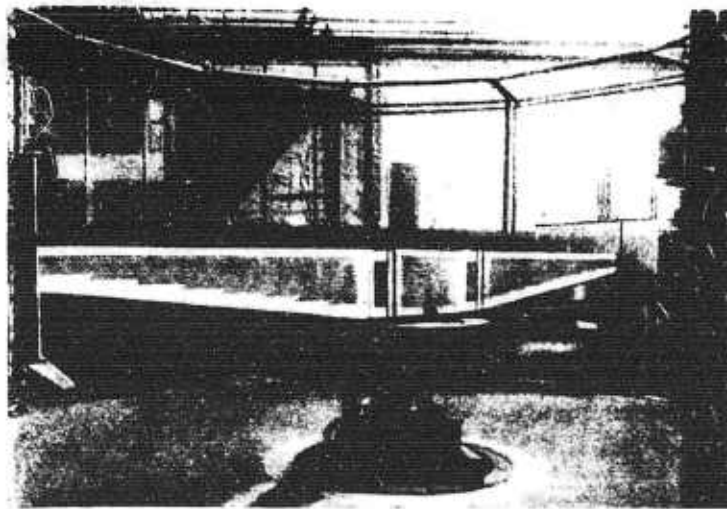
The facts described above follow rigorously applied scientific principles. They occur, without change, in the case of any pronounced transition from one velocity to another or in the case of a change in

the direction of motion.

Which is the force that is responsible for all of these phenomena? What is the nature of the origin of this force? In attempting to answer this question we must necessarily turn to the interesting physical phenomenon involved in an increase in the force of gravity.

A change in either the magnitude or direction of velocity per unit time is referred to as acceleration. With acceleration all bodies including those of a man and an animal experience the effect of mechanical forces whose magnitudes are equal to the product of the mass of the body and the acceleration. Since the mass of a given human being or an animal is a constant quantity, the magnitude of the mechanical (inertial) forces in this case will be directly proportional to the acceleration. The acceleration of a freely falling body serves as a measure of acceleration. Even Galileo, dropping steel balls from a tower, proved that any body increases its velocity by 9.81 m per second in straight descent. This acceleration is produced by terrestrial gravitation (denoted by the letter g , derived from the Latin word *gravitatio* - gravity).

In a study of the changes taking place in an organism experiencing the effect of acceleration, we generally measure those forces which force the person backward against his support, and we evaluate the force with which the man presses against this support, against the couch, the floor of the capsule, etc. During take-off we have the effect of the body weight plus an additional force which will be all the greater, the greater the magnitude of acceleration. If the acceleration of a freely falling body is equal to 9.8 m/sec^2 , or to one g , the increase in acceleration to two, three, or more g will indicate that the body weight of the human being during the time that these forces are acting upon him will be, respectively, two, three, or more times great-



One of the models of a centrifuge.

er than under normal conditions.

Imagine that an astronaut weighing 70 kg takes off vertically in a space vehicle and that he experiences acceleration of 8 g's for an instant during the take-off period. This means that during this period of time his weight increases to 560 kg ($70 \times 8 = 560$). It is natural that the shorter the duration of this acceleration effect, the more easily can a man or an animal withstand its effect.

How then are we to find out what happens with a live organism under the action of great acceleration? Will they succumb or will they remain alive, experiencing pronounced changes in their organisms? At what magnitudes of acceleration will such changes take place? And so forth. In order to obtain answers to these questions, special test stands, available both here and abroad, have been designed. Below we present a description of such a test stand.

We pass through a small and narrow corridor into an enclosure: this enclosure is circular in shape and we see a wide row of windows

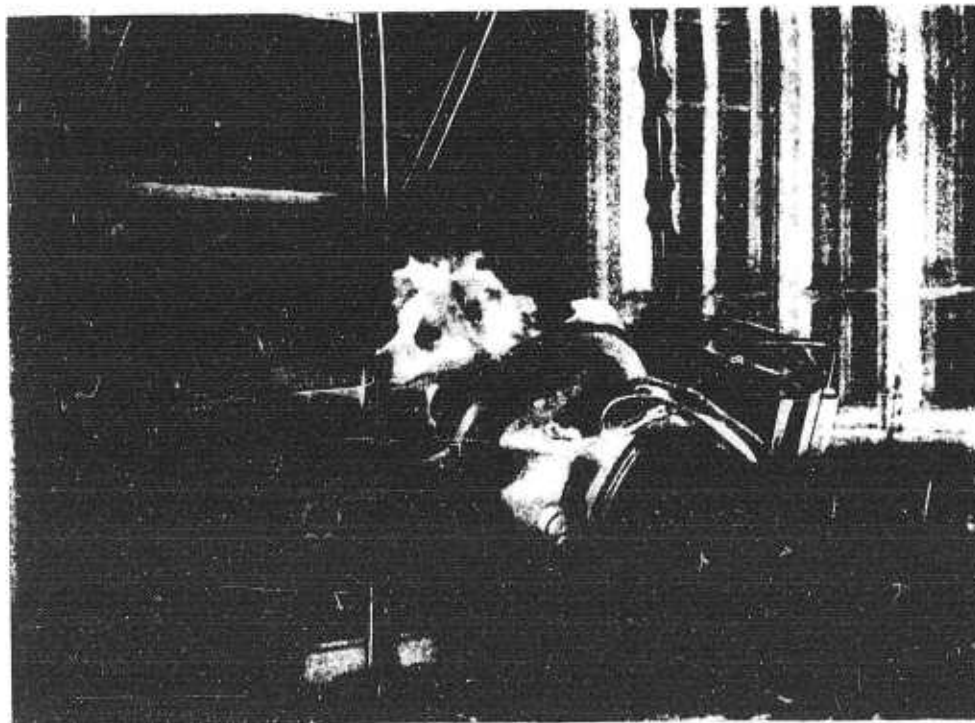
directly in the ceiling. It is light and clean here. In the very center of the room we find a strange structure. This is a centrifuge - a long steel girder which is reminiscent of a railroad-bridge span. It can be set to rotate by a powerful electric motor. A capsule has been mounted at the end of this girder, and a couch and the necessary instruments have been installed in the capsule. One can stretch out comfortably in this couch, placing his arms on the armrests and placing his legs on special footrests. The angle between the back and the seat can be changed at will - making this couch almost like a bed. The couch can also be adapted for dogs. Thus we provide the experimental conditions to study the effect of great acceleration on an organism.

Even K.E. Tsiolkovskiy employed the centrifuge to study the ability of an organism to withstand acceleration. The small capsule rotates ever more rapidly, and K.E. Tsiolkovskiy continues to increase its speed. Inside the capsule, in a special box, there are insects: cockroaches. Their weight increases by factors of 200, 226, and finally by a factor of 250. But they remain alive. Thus the scientist was able to establish that the cockroaches were easily able to withstand a 300-fold increase in their weight, and that a chick was able to withstand a 10-fold increase in its weight.

The centrifuge with which Tsiolkovskiy worked was imperfect. Technical achievements have made it possible, at the present time, to use powerful mechanisms for science that are capable of producing acceleration of great magnitude. Devices have now also been produced that are capable of producing and testing the effect of linear acceleration.

Here is such a device, described in foreign literature.

Imagine a small cart set up on rails and set into motion by jet engines. This car does not have wheels, but rather it slides along on special runners and is brought to a sharp halt by means of a special



Lisichka on the centrifuge before the training session.

water brake. The headlong run of such a cart (sled) is accompanied by a three-meter column of flame screaming in back. The sled runners slide over a layer of melted metal. A removable steel liner, approximately one centimeter thick, is almost completely worn down in a single run at a velocity of 2500 km/hr.

The guide rails of this device are made with exacting care: the

slightest error which would cause only a slight rocking of a car on a railroad track, would, at this speed, result in a catastrophe. In the USA such a reaction-powered sled, moving along guide rails in an unmanned test, attained a velocity of 3500 km/hr and a 100-fold acceleration.

Problems relating to the effect of acceleration on an organism were, for a great many years, the main concern of many Soviet scientists. These problems continue to be urgent and vital at the present time.

It has been established as a result of a great many experiments that insects are able to withstand acceleration which increases their weight by a factor of 2000 for periods of 1-2 minutes. Frogs can stand to have their weight increased by a factor of fifty. Cats, by a factor of twenty. Dogs remain alive at such acceleration, with their weight increased by a factor of 80 for five minutes, in which case a small Eskimo dog would, for example, weigh some 480 kg, i.e., almost half a ton. But let us return to the building in which the centrifuge is housed.

Here we find a scientific coworker working on problems relating to the effect of acceleration on an animal organism, and he is checking the medical equipment that has been installed aboard the capsule. He again carefully examines the electrical wiring connections, switching various instruments on and off in sequence. A laboratory assistant quickly fastens an animal into the couch and she draws the straps tight, around the small body of the dog, making absolutely certain that they do not press too tightly and are comfortable for the animal.

Little grey Marsianka with her smooth and silvery fur is sitting quietly, without moving, carefully and in great alarm following everything that is happening around her with her eyes. The animal has become accustomed to the various experiments and has been trained to

behave with great "self control." However, Marsianka is in the couch of the centrifuge for the first time.

The last preparations are under way. The entrance door is closed. Any entry into the building with the centrifuge during a centrifuge test is categorically forbidden, since it is very dangerous. The command is given: "Start the motor."

The capsule containing the dog slowly moves from its position. For the last time we can clearly see the body of the animal, her snout, and her perked-up ears. The couch moves in a circle, and ever more rapidly. At the same time it deflects upward and after a short period of time the capsule is on a level with the horizontal frame.

An engineer sets an indicator and announces loudly: "two," "three," "three and a half." This means that the weight of the capsule and everything in the capsule has increased by a factor of two, three, and three and a half.

On hearing each new number the worker in charge of the experiment notes down the blood pressure, the respiration, and other physiological functions on the paper tape on which the electrocardiogram is being recorded. These notes make it possible, subsequently, to determine how all of the characteristics change as the acceleration increases and then, conversely, what changes occur with a reduction in acceleration. The stylus recording blood pressure draws out an even row of peaks. The paper tape is moving and as the magnitude of acceleration rises to an increase by a factor of 4, the peaks become elongated and change in shape. The velocity continues to increase. "Five," says the engineer, "six," "six and a half."

The acceleration is so great that if you imagined that Marsianka were sculptured out of lead - an extremely heavy metal - she would still not weigh as much as she does now.

When the curves obtained on the tapes of the recording instruments are deciphered, it will be possible to judge clearly as to the changes in the animal's pulse, arterial pressure, respiration, and remaining physiological functions.

Particularly great attention is being devoted to the behavior of dogs during the action of acceleration, and a special motion-picture camera, mounted on a bracket and directed at the animal, is of great assistance in this project. The dogs fastened to the couch behave comparatively quietly. While acceleration is not yet very great, they can move their heads and they try to keep them raised. With increasing weight movement becomes more difficult for the animal and the head begins to bounce in an uncontrolled manner, and is finally pressed back against the couch.

The situation is particularly difficult for dogs that are not tied down. In this case, they at first manage to sit in the couch. As the centrifuge begins to rotate their front paws begin to slide. The animal at first actively tries to overcome this effect, but then simply assumes a lying position in which it is more comfortable for the animal to withstand the rotation. Here we see Belka, not tied down, striking the wall of the capsule. Her front paws are slipping and the dog cannot move them together; she lies down, and her head and the relatively free front part of her trunk are pressed against the couch with tremendous force. Linda began to bark as the centrifuge began to turn and the weight of the dog almost tripled. Her barking was rather infrequent at first, but picked up in frequency as the speed increased.

After Marsianka, Zhemchuzhnaya and then Lisichka and Gil'da were subjected to the experiments on the centrifuge. And the same thing was done to all of the selected dogs. On the basis of how their basic physiological indicators change under the action of such powerful distur-

bances, we are able to arrive at a conclusion regarding the suitability of these animals for flight.

It was not too long ago that Layka, and subsequently Strelka and Belka, and later on Zvezdochka and Chernushka were subjected to all of these tests; these first four-legged astronauts were well prepared for the effect of acceleration. Soviet scientists were able to prove, with pride, that this training procedure had been properly organized. The decoding of the signals showed that the animals were able to withstand satisfactorily all aspects of acceleration during the period preceding the entry of the satellite into orbit. Only the number of their heart contractions increased slightly, and there was a slight increase in the respiration rate, both phenomena that are usual in the case of such acceleration.

There are also centrifuge devices with hermetically sealed capsules, thus making it possible to pump out the air, changing the gas composition within the capsule, and to produce various temperatures within the capsule. The simultaneous effect of acceleration, the rarefaction of the air (flight "altitude"), temperature factors, etc., can be studied on such a centrifuge.

The centrifuge is controlled from a console situated in the center of rotation or (in the latest models) above and to the side of the centrifuge. A machine of this type can be accelerated to tremendous speeds within a very few seconds. This makes it possible to attain substantial acceleration. Observations of the animals during their rotation are carried out by means of television installations and motion-picture cameras. Simultaneously, there is a continuous electrocardiogram record, as well as records of the biological currents of the brain, blood pressure, respiration, oxygen saturation of the blood, and x-ray photographs are taken.

The animals are observed on the centrifuge not only for the purpose of selecting those most suitable for flight training, but to clarify many of the problems relating to general theory. In preparing the training schedule for a manned flight into outer space, it is important to know how acceleration affects a living organism.

VIBRATION AND NOISE

We have before us a small rather ineffective looking device that is similar to a wide post. It reaches somewhat higher than a man's belt. A motor is started and the upper smooth metallic platform of this device begins to shake. If one were to place the palm of his hand on this platform, the hand would experience minor but persistent impulses. These produce uniform shaking in the surface tissue at first, and soon the muscles are carried into this motion, and finally the vibrations reach the very bones. It turns out that this insignificant looking device is capable of generating great force. In order to mount this device it was necessary to break up the floor and to lay a special foundation: otherwise the impulses imparted to the walls of the building during the operation of this device would gradually destroy the entire structure.

When the device is on there is great noise. This noise penetrates deep into the ears and paralyzes all other sounds, making it difficult for any people present in the room to carry on a conversation.

We are now in the building in which this device has been set up; this is a vibration stand, an apparatus designed to produce vibrations (oscillations, trembling, shaking).

During the take-off of a rocket or a satellite, all structures, instruments, and living beings experience strong vibration. These vibrations occur as a result of engine operation and may be of such small frequency and great amplitude as to be felt simply as shaking, or they

may be such high-frequency oscillations as to approach the area of sound.

Various vibrations act differently on the organism. It is for this reason that it is necessary to determine the nature of the physiological changes that occur in a living organism under the action of vibrations.

The tremendous wealth of scientific literature which has been devoted to the effect of vibrations answers this question only partially. On the basis of these materials one might think that the effect of short-term general vibrations have no substantial destructive effect on the activity of the organism. It has also been established that in the case of the repeated action of vibrations the organism becomes accustomed to the vibrations (it becomes adapted). This served as a basis for a number of experiments directed at training dogs to withstand the effect of vibrations.

The noise that accompanies the operation of the vibration stand also serves as a factor which will act on the dogs during the take-off of a rocket. Of course, it may turn out that the force of this noise, and the nature of the component tones, etc., will be of a different type in this case, but there is no doubt that there will be sounds that produce a particularly intensive effect at that time.

As is well known, noise affects the nervous system of both animals and man, in certain cases producing increased stimulation, whereas depression is introduced if the noise is prolonged. It is also well known that no adaptation to a powerful sound is possible and, therefore, it is impossible to train a dog to withstand noise by weakening its effect. Something else must be done, and namely to train the animals "not to be frightened" of loud aural stimuli. And this is extremely important, since the over-all unfavorable background for the nervous activity of

the organism is thus immediately removed.

Let us stop for a moment in the laboratory housing the vibration stand and let us take a look at how the work is progressing here.

Mushka, a white little dog, is placed into a cradle covered with soft material; this cradle is fastened to the vibration stand. Mushka is dressed in her entire experimental outfit. Wide straps hold her fast in the cradle. The animal is quiet, and without "terror" follows everything that is happening around her, occasionally wagging her tail.

A scientific coworker connects the wires from the sensors attached to the animal's body to the electrocardiograph (during the vibrations the dog's electrocardiogram will be recorded). The respiration sensor is connected to another instrument. For the purposes of blood-pressure research a cuff is placed on the carotid artery.

Everything is ready and the vibration stand is turned on. At first the vibrations are not very great, and the knocking noise is only beginning to increase.

But what is happening to the dog? After a very short orientation reaction the dog is completely alert and her ears are perked up. Within a second the animal attempts to stand up and strains at her straps. Now the entire appearance of the dog clearly shows "terror": the support that had always been stable is now shaking and trembling beneath the animal, and the noise is becoming more intense, filling the entire enclosure.

The recorded curves show a rise in blood pressure, and more frequent heart contractions. The dog's respiration at times drops virtually to zero, and then begins to increase.

But don't jump to the conclusion that all of this is a result of the effect of vibration. Similar changes may be produced by the pronounced "excitement" experienced by a dog finding itself under unusual

conditions: at the moment the animal is clearly excited. We will be able to render a judgment regarding the influence of vibration only after the dog has quieted down, and ceases to react so violently to the experiment and the noise produced by the vibration stand.

The experimenter is gently petting Mushka. The animal grows noticeably more quiet, but as before there is "terror" in its eyes, and as before the recording instruments show that significant changes in the physiological indicators have taken place.

The dog behaves in approximately the same manner on the following day as well. This indicates that she has not yet become accustomed to these conditions. In other words, one or two vibration disturbances are inadequate in order to determine the changes that take place in an organism under the influence of such disturbances, and they are particularly inadequate to train a dog to withstand the conditions of this particular experiment.

The experiments on the vibration stand are repeated on a regular basis, with intervals of one or two days. Mushka, just as all of the remaining dogs selected for space flights, begins gradually to withstand more quietly the powerful shaking and the continuous noise.

It is now that the reactions of the animal, produced by the "excitement," already inhibited, can show how vibrations affect the dog. The instruments show that respiration speeds up to 40-50 respiratory cycles per minute, and within another two and a half minutes respiration becomes even more frequent and shallow. At the end of the vibration test, the breathing process slowly returns to normal. The pulse frequency also increases substantially (from 120 to 220) and returns to normal after 15 seconds after the vibration stand has been turned off.

Similar changes in the autonomic functions in the case of vibra-

tions (of course, with certain variations) can be regarded as normal, since they are typical for all animals that can withstand vibrations well.

At the end of the experiment the laboratory assistant frees the dog and we note that Mushka is remarkably passive whereas she is normally quite active. She reacts weakly to the presence of a human being and his petting, something that had earlier caused the dog much "happiness." The animal quickly falls asleep in the arms of the laboratory assistant.

Drowsiness is a usual reaction which sets in for the majority of dogs after experiments involving the vibration stand. Sleep is the general wholesome inhibition of the cerebral cortex, which rapidly restores the dog's strength enabling the animal quickly to behave in its accustomed manner.

The laboratory assistant now finds another astronaut candidate to the cradle that is fastened to the vibration stand.

THE HIGHER NERVOUS ACTIVITY OF EXPERIMENTAL ANIMALS

The study of the higher nervous activity of animals plays no mean role in their training for flight.

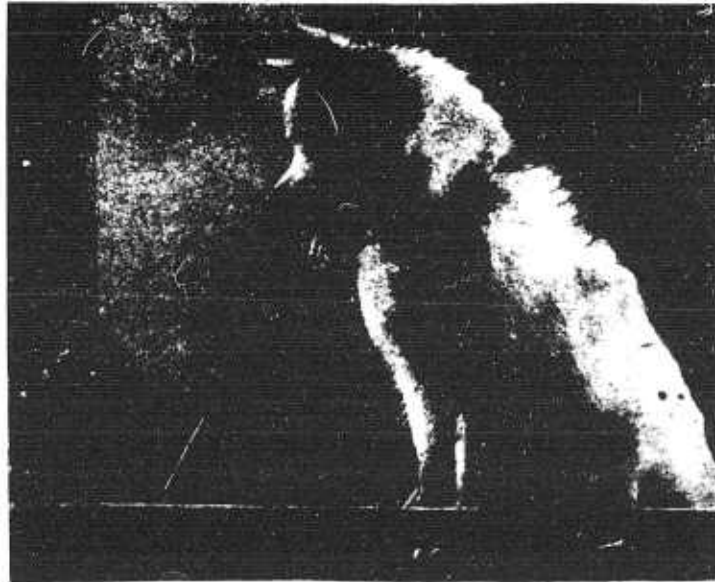
There is much that is complex and unexplained in the higher nervous activity. How are we to begin, how are we to understand this complexity, and how can we express all of this in the language of precise data?

Science has long been confronted with these questions, and their complexity has frightened off many investigators. This is particularly true of behavior problems and the physiological characteristics of receptor and motor activity of animals. Many nonscientific and subjective false theories appeared as a result, or schemes that were completely devoid of any point.

And thus in Russia in the beginning of this century there appeared the investigations of I.P. Pavlov. His projects are of tremendous significance. Pavlov succeeded in finding a method of analyzing complex nervous reactions and isolating that simple phenomenon which acts as the elementary cell of complex forms of behavior. This is reflex, i.e., the response of the nervous system of an animal to some stimulus. Reflex, in the work of the Pavlovian school, serves as the index of the complex physiological processes taking place in the brain; the behavior of animals is regarded as inseparably associated with the activity of their cerebral cortex. As a result of the investigations carried out by I.P. Pavlov over a period of many years, he was able to formulate the basic quantitative relationships governing the higher nervous activity of animals and he developed methods of studying this activity. These investigations were the significant contribution to the solution of practical problems in the field of domestic biology and medicine.

Before us we have the usual narrow installation, used in all laboratories, for the "fixation" of dogs. This installation is situated in a special enclosure that is also available in all physiological scientific laboratories. The walls of this installation are soundproof, thus making it possible to isolate the animals as much as possible from external stimuli.

A door opens and a lively and active dog, Pushinka, quickly and without waiting for an invitation jumps into the installation. Complex motor reflexes have been developed in our dog, and these are a response to various aural and visual stimuli. Light signals (red, yellow, and green) appear on the panel of a small instrument situated at a slight angle to the test stand. In front of this board there is a keyboard, i.e., three rectangular planks touching one another. Beneath this unique piano we find a container of food. The laboratory described here



If the right bulb does not light up, there is no point in getting up.

has been adapted to develop conditioned reflexes in dogs.

In a study of the so-called autonomic processes (blood pressure, respiration, pulse, etc.), we must record changes in phenomena already present in an organism. However, if it is necessary to obtain materials which characterize the higher nervous activity, it becomes necessary first of all to form a definite behavioral pattern in the animal and to produce that which is to be subjected to analysis. It is precisely this which is the prolonged and frequently difficult process of developing conditioned reflexes.

The dog must be trained to carry out specific movements in response to certain stimuli. As a result the animal develops a rigorously defined system of behavioral reactions. The nature and form of individual elements in these reactions, their sequence, their interrelationship are all known in advance to us. Thus it becomes possible to simplify the

complex forms of behavior, making the latter accessible to analysis.

Pushinka had long ago developed a clear system of reflexes. Take a look at the instrument which produces the stimuli and records the reactions; you will be amazed to find that the animal seems somehow "to be mounted" in this unit, and reacts only at the required instant of time and only when a particular action is called for.

The experimenter assumes his usual position at a table in the room adjacent to the capsule. Before him there is a variety of equipment. The electric second timer is switched on. Switches are clicking and the white paper tape in the recording instrument begins noiselessly to crawl along. Five styluses will record everything that is happening in the capsule (the switching on of the signals and the response reaction of the animal). The second timer, having clocked 60 seconds, actuates the first stimulus. A unique sound passes through the capsule. The experimenter who is looking through a special slit can see how the dog "busily" and "happily" reacts to this sound: she rises quickly and stretches her entire body forward, and her fluffy tail begins quietly and regularly to beat against the plexiglas wall of the installation. The animal turns its pointed snout to the signal board, and its ears are perked up; now the entire appearance of the animal is one of extreme attention: which lamp will light up?

The red light flashes. Pushinka carefully places her paw on the end of the plate, presses down, and looks to see if the food container opens. (The contact must be exact: down the middle plank, from top to bottom, with a force not less than 50 g). The click of the opening cover, and the animal sees its favorite delicacy (a piece of sausage).

If a green light flashes on the panel, the dog remains quiet as if "aware" that this light indicates something quite useless and regardless of how much she were to press down on the plate, the food container



A contact must be exact.

would not open. It was not always thus: for a long time Pushinka was "unable" to distinguish (differentiate) between the lights flashing before her.

By the way, she sometimes makes mistakes even now, reacting to the green light just as she does to the red. This phenomenon is the so-called "disruption of differentiation" and indicates the predominance of an excitatory process in the cerebral cortex of the animal at this particular instant in time. Thus mistakes in Pushinka's actions make it possible to characterize the state of the processes taking place within the animal's cerebral cortex. Let us imagine that some disturbance such as, for example, vibration, noise, or all of the "conditions" of flight, have brought about a disruption of brain activity. The technique of conditioned reflexes will enable us to establish exactly the nature and specific features of these disruptions.

In this particular case the nature of the motor reactions of the dogs are of great significance. The experimenter devotes particular effort to associate movements with definite signs: first of all, a particular direction (the dog guides its paw from the narrow distant end of a trapezoidal plank to its wider end), secondly, the movement must always, without exception, take place in relation to the middle plank and, finally, thirdly, the movement must in this case be carried out with a force of not less than 50 g.

Only if she complied with all of these conditions did Pushinka obtain access to the food. This explains why the animal's movements are so standardized. It is understandable that the development of such complex reactions required much effort, patience, and love for animals.

Changes in the developed motor habits of the animal during flight make it possible to render a judgment regarding the effect exerted by flight factors, primarily by weightlessness, on coordination of movements. It will be important to observe how the form, the strength, and the direction of motion change, or perhaps the animal will cease its accustomed movements entirely.

The developed system of reflexes will also enable us to answer a number of questions that relate to the process of receiving signals under conditions of weightlessness. Will the animal be able to perceive light or react to unaccustomed sounds? An instrument will enable us to characterize exactly, in numbers, the motor reactions of the animal, and this in turn will make it possible to analyze precisely those processes taking place in the cerebral cortex which underlie the given activity.

Let us present an example of the effect exerted by a powerful external disturbance on the conditioned-reflex activity of a dog. Pushinka, just as all of the dogs that have been trained for flight,

is subjected to the disturbance of acceleration. After 9 minutes the rotation on the centrifuge is stopped. The dog is lying down and it seems as if she were dead; however, she raises her head and looks around. The laboratory assistant quickly unties the animal. Within 7 minutes Pushinka is back in the familiar installation in which the conditioned reflexes were developed. There is a click and the dog, without waiting for the flashing of the light, begins to turn restlessly. Her movements are numerous and chaotic. This same salvo of confused reaction is observed in response to the green light (which generally produces no movement on the part of the dog), and the dog behaves in similar fashion in response to the "useless" yellow light.

After the application of the sixth stimulus, the dog suddenly stops reacting entirely, even to the red light; if she reacts to the red light at all, it is only with extreme sluggishness.

On the morning of the following day Pushinka "is working" but not as well as always; however, later on she is found to work very well.

What do all of these facts indicate? They make possible the exact determination that individual regions of Pushinka's cerebral cortex were stimulated immediately after being subjected to the centrifuge. This explains why the dog was unable to distinguish the signals, something that she was able to do easily prior to the experiment. This explains the confusion and the hasty movements. After 15-20 minutes predominance of inhibition developed in the central nervous system and the dog was no longer able to execute well the movements to which she had been trained. This is also shown by the behavior of the animal (sluggishness, the effort to lie down). The predominance of inhibition processes was noted in almost all of the dogs sometime after the action of acceleration.

Pronounced inhibition of conditioned motor reflexes after a rocket flight was noted in the case of Malek. The dog "did not want" to execute any of the required movements, and it twitched in response to sounds which denoted food and "gladdened" the animal prior to the flight.

Neva, a fluffy and white dog, less famous than Malek, shared with the latter all of the vicissitudes of the life of experimental animals. In her case, just as with Malek, a system of reflexes was formed and then intensified. Carrying out the role of a control animal, she traveled together with Malek to the point of rocket launch and was kept there under the same conditions, ate the same food, etc. However, she did not fly into the cosmos. And what happened? This dog did not give the impression of being frightened or tired, but on finding herself back in the installation after an extended interruption gladly and busily executed all of the actions for which she had been trained.

It is interesting to note that in all other respects (cardiac activity, respiration) Malek exhibited almost no changes after the flight. Consequently, the conditioned reflexes represent the clearest indication of the disturbing effect that unusual factors in the external medium exert on the animal's organism. These reflexes are disrupted before it is possible to detect any other changes.

Observations of changes in the higher nervous activity of animals after a flight forces us to the assumption that the conditions of flight will also have an effect on a human being, and they will affect primarily the functioning of the cerebral cortex, initially producing here an intensification of the stimulatory process, and then the predominance of the inhibitory process.

It should immediately be stipulated that a man with a strong will may not exhibit any behavioral changes, since the behavioral reactions

of a man are much dependent on volitional impulses. It is clear that it is impossible automatically to transfer to a human being the results obtained in observations of dogs under conditions of the space experiment, particularly if this pertains to the central nervous system. However, the general quantitative relationships governing the reactions that are characteristic for any representative of the animal kingdom will, apparently, apply to a man as well.

SPECIAL DISTURBANCES

A structure of strange shape is situated on a small platform surrounded by a low fence. This structure resembles a raised portion of railroad track set up on a special foundation: it looks as if a section of the track (the rails and the ties) had been taken and stood almost vertically on end. Stairs reach through the middle of this structure and come to a stop at a special platform. At the bottom of the structure we find a bucket seat which can slide upward along the guide rails.

In back of the couch we find the so-called propulsion mechanism: two shafts, one inside the other. The inner shaft is connected to the couch and the outer shaft is connected to the base carrying this structure. If a pyrocartridge were placed inside the inner shaft and the capsule were fired, there would be a shot. The powder gases would act against the piston and the piston would act on the couch which would move upward, rising along the guide rails. Depending on the carefully measured charge in the pyrocartridge, more or less momentum could be imparted to the couch and the height to which it rises could be controlled. So as to prevent its leaving the rails, a special stop has been installed at the upper end of the guide rails.

There are also horizontal guide rails and they can be much longer. All of these are so-called catapult devices.

When an airplane flies at a velocity in excess of 600 km/hr it is

impossible to leave the airplane by conventional methods in the case of an emergency. The muscular strength of a human being is inadequate to overcome the pressure of the approaching air stream. At the present time ejection (catapulting) of the pilot together with his couch is the basic method used to effect an emergency departure from high-speed aircraft. The couch receives its initial momentum from the explosion of the pyrocartridge, and the couch together with the pilot is ejected from the aircraft at great speed.

Acceleration of short duration is produced by the explosion, and this results in extremely great G forces. The magnitude of these G forces is a function of the force of the exploding gases. Because of their short duration, such G forces are analogous to a shock. Therefore they are referred to as "shocks."

On 4 September 1960 the newspaper "Pravda" published the basic data on the equipment aboard the second space vehicle, and the article also described the various stages of the flight. In particular, the article described how during the descent stage, at an altitude of 7000-8000 m, in response to a command issued by the barometric relays the cover of the catapult hatch was detached and the container with the animals (the dogs Strelka and Belka and other living beings) was ejected from the capsule of the vehicle.

This is a clear and dry report, but it required a tremendous amount of work before these simple lines could appear on the pages of the newspaper—we have reference here not only to the work of the designers, but of the work of the biologists and doctors who had to resolve a number of problems during the preparation for this biological experiment.

The first and foremost of these problems were the following: what was the shock acceleration that the dogs were able to withstand? In what direction were the effects of these accelerations best withstood?

How should the animals be restrained? On the answers to these questions depended the selection of the size of the pyrocartridge charge that was required, and these answers also determined the speed of capsule flight, flight altitude, etc. In a word, it was necessary to solve many important problems of practical significance.

We see before us the catapult installation which has been adapted for experimentation with animals. There is a dog in the installation and the animal is dressed in its restraint clothing, and it is fastened to the couch.

There is a shot and the cart moves at a colossal speed along the guide rails of the installation. In an instant the cart has reached the end of the guide rails.

The frightened animal that has just experienced powerful shock acceleration is released. But within a minute or so the behavior and external appearance of the dog returns to normal.

The doctors carefully examine the dog's skin, sclera of the eyes, and the ears to see if there is any hemorrhaging. They feel the muscles and they make a series of x-rays: it is important to determine whether or not the animal has suffered any bone damage. The examination shows that there is hemorrhaging, but not serious. The dog stands quietly as she is pinched and this indicates that this pinching is not painful. The x-rays are also reassuring: there is no bone damage. Thus it has been possible to establish the maximum acceleration magnitudes which a dog can withstand without serious injury.

Such experiments, with subsequent medical examination of the animals, were carried out repeatedly on various dogs. All of the dogs withstood relatively well the shock acceleration that is anticipated in actual flight.

It was also brought out that with repeated catapulting the physio-

logical indicators (respiratory rate and pulse rate, arterial pressure) remain the same as during the first disturbance (catapulting). Consequently, the dogs probably do not become adapted to such powerful disturbances.

The descent of the dogs from an altitude of eight kilometers during their parachute landing also calls for the solution of problems relating to the ability of the animals to breathe under conditions of an extremely rarefied atmosphere. How are the dogs affected by this altitude, what changes take place in their organisms? How long does the organism require, after having been subjected to these aforementioned changes, to return to normal?

In order to clarify all of these points, we have a so-called pressure chamber at our disposal. By means of special pumps it is possible to evacuate the air from this chamber very quickly, thus producing the rarefaction which corresponds to a particular altitude.

A dog is brought into the pressure chamber and fastened so that the dog can be seen easily through a special large observation window. The door is closed and the locks are fastened tightly. Then the pumps are turned on and, controlling the speed of air removal (rate of "climb"), the required rarefaction of the air - "altitude" - is produced in the chamber.

The dog is seen to be standing in the chamber as if nothing were happening; the dog is looking at the door and at the observation window. Occasionally she moves her feet and wags her tail. In other words, her behavior is quite normal.

The indicators on the instruments show a rarefaction that corresponds to an altitude of five kilometers, six kilometers, etc. The animal shows changes in pulse, arterial pressure, and its respiration becomes faster and shallow. However, her behavior indicates that none of

this represents any danger.

There is no need to test the effect of great rarefaction on the animals: after all, this will not be encountered under conditions of flight, since it is planned to catapult the dogs no higher than an altitude of eight kilometers. Once convinced that everything is proceeding properly, we conclude the experiment in the pressure chamber.

Thus it was shown that healthy dogs are well able to withstand an altitude of eight kilometers and with repeated "ascents" their organisms adapt to the conditions existing in a rarefied atmosphere.

An extremely urgent problem from the standpoint of engineering is the one involving the establishment of the required temperatures in the capsules of space vehicles. Protection must be provided against possible high and low temperatures both during the flight and during the return of the vehicle to earth, when the rocket undergoes pronounced heating as a result of the friction between the frame of the vehicle and the air of the atmosphere.

In seeking the solution to this problem it was important to determine the ability of the dogs to withstand the effect of both high and low temperatures.

It is also important to bear in mind the unexpected occurrences that may arise in such an ambitious undertaking as a space flight, and everything in our power should be done in order to prepare for these chance occurrences. Even the slightest deflection of the vehicle from its set heading on return to earth will result in a significant change in the anticipated landing point. As a result the dogs may find themselves in the most varied of climatic zones in which temperatures may be either very high or very low. If to this we add that the time required to find the capsule in such a case may be quite great, it becomes clear that the problem of the limits within which the animals

can withstand changes in temperature becomes one of primary significance.

We know that dogs do not exhibit great stability to pronounced changes in air temperature, and this applies particularly to a rise in air temperature. In great measure this pertains to those of the dogs which are accustomed to room temperatures and have short thin fur. Moreover, we know how important it is, in the case of frost, to move vigorously, and how important it is, in the case of heat, to remove excess clothing and to drink water. The experimental animals are deprived of such possibilities: the small capsule restricts their movement and they cannot and may not remove their clothing, and they have no water which is not part of their food.

The ability of dogs to withstand a drop in temperature is studied in a special experiment. The capsule with the animals is placed inside a large chamber that has been equipped with a refrigeration installation. After a period of two hours the dogs find themselves under winter conditions: -17° , and then later on -20° . The frost becomes more severe: -25° . Seemingly, there should be nothing unusual about this: there are many dogs which spend their winters in little huts that are barely heated.

However, experimental animals are another matter. Their breathing becomes less rapid, but deep: as a result there is less loss of heat. It would be a good idea, at this point, to feed both Zhuchka and Achka to their hearts' content with warm food (the food, replenishing the store of energy in the dogs' organism would help them to overcome the cold). But it turns out that they are completely unable to eat, since the food in the automatic feeding device is frozen.

Numerous experiments have shown that the dogs are satisfactorily able to withstand a frost of forty degrees in the capsule, but there is risk involved in any attempt to lower the temperature any further.

If asked which is more terrifying - great cold or great heat - most people would in all probability answer that it is cold that is more terrifying, whereas the dogs clearly have greater difficulty in withstanding the effect of heat.

The situation involves the fact that if a man finds himself in danger of becoming too hot there are compensating mechanisms that come into play and these are capable of removing the excess heat from the organism (expansion of cutaneous vessels, perspiration, more rapid breathing, etc.).

Dogs exhibit fewer of these adaptive reactions. Recall the appearance of a dog on a hot summer day. It moves slowly, lies down much of the time, its muscles are relaxed, its tongue is hanging out, and breathing is rapid and shallow. All of this occurs at a temperature of 25-27°. This is a result of the fact that there are virtually no sweat glands in the cutaneous covers of any of the representatives of the canine family. They sweat through their tongues and, to some slight extent, through the pads on their paws. Therefore, the excess heat in the case of high air temperature can be removed only by a more rapid rate of respiration. Thick fur also does nothing to enhance the cooling of the animal.

An experiment is in progress... Slowly the temperature in the chamber rises. Denek and Pushok withstand this increased temperature well at first. Occasionally, Denek can be heard barking, but the sound is muffled by the walls of the capsule.

Gradually the respiration rate of the dogs becomes even more rapid: They begin to breathe 142, 154, 208 times per minute, and the pulse rate climbs to 190 beats per minute. The animals feel ever poorer and poorer. Initially there is a pronounced loss of appetite, and then no appetite at all. It is strange to see how a dog which eats as voraciously as does

Pushok fails to touch its food after having made one or two passes with its tongue at the food in the box that opened before it.

So long as the air temperature continues to rise, the heat-control mechanisms in the animal are totally unable to perform their functions. And if the experiment is not cut short, the dog may succumb.

The ability of dogs to withstand various temperatures was determined under a great variety of experimental conditions. The reactions of the animals in the case of both slow and rapid increases in temperature were tested, as were the reactions at various degrees of restraint, in the case of a plentiful supply of water, in the case of restricted water supplies, etc. Special forms of food were prepared for these experiments (for the experiments involving cold, the food was prepared in pieces of a nutritious mixture that could not freeze; and for the experiments involving heat, the food was prepared in the form of a mixture containing a large quantity of water).

As a result of these experiments the limits of the dogs' resistance to changes in ambient temperature were established for "conventional" positions of the animal in the capsule, and the effect of various nutritional mixtures on the ability to withstand high and low temperatures was also determined; in addition, the behavior of the dogs under these conditions was studied.

All of this aids in the effort to understand the phenomena which take place during flight. The experiments that have been carried out also made it possible to answer a number of questions that were of interest to the designers.

COMPLEX PHYSIOLOGICAL EXPERIMENTS

Thus the dogs passed all forms of tests. They can spend a prolonged period of time in the capsule without movement, and they can withstand great acceleration and vibration. The animals are not frightened

by various noises, they can sit in all of their experimental attire, thus providing the possibility of recording the biological current of the heart, the muscles, the brain, the nature of respiration, arterial pressure, etc. The dogs have been trained separately for each of the required disturbances.

And now, after a well-deserved rest enabling the animals to recover their strength, they find that they have yet another important test before them - a complex physiological experiment. The animals will be subjected simultaneously to a great many disturbances and the various functions of their organisms will be systematically recorded. Such a complex experiment is carried out in surroundings that approximate to the greatest possible extent the conditions prevailing in space flight; this experiment serves as the dress rehearsal for the great experiment.

The long and careful preparations indicate that the scientific workers treat this complex experiment as a serious laboratory test. And this is understandable, since here we determine the value of each individual section of the job and the slightest trifle acquires great significance. It is everyone's wish that any and all of the achievements, checked prior to this in many individual experiments, agree and fall into place with the other results, and that each of these achievements becomes an integral and necessary part of the great experiment. Any failure in this experiment, even the slightest errors in the way the experiment is carried out, can endanger the possibility of flight, since flight permits of not even the most minor of infractions.

Now let us turn to the preparation and execution of such a complex experiment. We are in a large sunlit room with a high ceiling; this is the center of turmoil and activity. We see some 5 to 6 engineers and technicians, doctors in white tunics, biologists, chemists, etc. All of these individuals are responsible for various aspects of the project:

for the condition of the animals, for the proper functioning of the individual mechanisms and instruments, etc.

We see an open chamber shaped to resemble a bell in the center of the room. This chamber is approximately twice the height of an average man. There are some metal boxes at the base of the chamber, and two walls of these boxes resemble the radiator of a car - this is the regeneration installation containing a chemical substance that is capable of absorbing carbon dioxide and evolving oxygen. Higher up we find the automatic feeding device and then there is a small capsule for the animals, and the capsule is provided with screened walls and a cork floor. There are a great many instruments all over the place. Enclosed in light-gray frames, they are suspended from the top, from the sides, and some are positioned beneath the chamber. There is a mass of wires, bright and variously colored: yellow, blue, green. This makes it possible easily to check whether or not the instruments have been properly connected. Next to the chamber stands a glistening silvery cone-shaped cover.

One technician is engaged in the installation of the control panel, another is working on the ventilator, a third is soldering the wires. We can hear the scraping of a file and the sounds of a drill. Individual component parts are being adjusted, tanks are being attached, and the heat sensing elements are being fastened.

In the building next door the dogs are being readied: Strelka and Belka are to be placed into the capsule. The dogs are being washed in two baths with soap and a soft brush, they are rinsed off, and then dried before a reflector. Cleaned, dried, and combed, they [the dogs] enter the operations room. Here the points on their bodies at which the electrode leads come out are carefully and thoroughly smeared, the animals are bandaged, and a green "shirt" of thin material is put on

each, the shirt designed to protect the bandage against contamination and to prevent it from twisting off. The dogs, accustomed to these procedures, stand quietly without moving, occasionally wagging their tails.

After this, the respiration sensor is put on the animals; this is a "vest" that fits tightly around the animal's chest; finally, the sanitation and restraint clothing is put on. Sensing elements to detect movement are sewn onto the restraint clothing. The paws, snout, and tail of the dogs stick out from the green suit; sticking out of the back we see hanging a rubber connecting tube, and there are many variously colored wires coming down from the back and from the sides.

The final preparations are in progress everywhere. Work is being done to adjust the sanitation tank. The animals are picked up and placed into the capsule. The connection tube from the sanitation clothing is made fast. The dogs stand quietly while people work to separate the wires coming out of their bodies, the straps are properly tightened, and the chains are fastened. At the very last instant the cuff is placed on the carotid artery which, as was described earlier, has been brought out in a skin sack, thus making possible the recording of arterial pressure. A technician, carrying a soldering iron, is attaching the wires used for the recording of the biological currents to a special block that is fastened to the capsule. The connections of these wires are checked and resistances are measured.

Now the moment is at hand when everything seems ready. The sound of work dies down. Everyone now awaits the command of the individual in charge of the experiment. He carefully checks over each project sector in succession, issues last-minute instructions, and on a pad we see notations of "done" for each sector. The laboratory head then checks the quality of the work rapidly, with an experienced eye, and

if he has no corrections to make, he says quietly: "I see no reason why we cannot begin the sealing off of the capsule."

And again movement begins around the capsule. The cover of the capsule is raised and then slowly lowered to cover the capsule. We see the "bewildered" dogs for the last time in the darkness that is setting in around them. Although the lowering of the bell does not threaten them in any way, they strain at their strong leashes and bark. And now the closed capsule is before us in the room. It looks like the cap of a giant, shaped like a cone, glistening, and the observation window gives the appearance of a diamond set into this cap. It is strange to look at this surface which had just recently been covered with a great variety of connections and interlaced shapes, tubes, and wiring. The complex experiment has begun.

This chamber will be kept in operation for many days: ten, fifteen, twenty, exactly how many depends on the specific assignment in each case.

Everything in the capsule has been automated to the greatest extent possible and the capsule has now been converted into what seems to be a self-supporting being. Communications with the outside world are maintained by means of the signals which detail the processes taking place within the capsule. A red bulb lights up. This means that the pressure in the capsule has increased. Immediately thereupon a green light flashes, reporting the activation of the chemical substance which absorbs the carbon dioxide and water vapors; this substance will restore normal pressure. There is a lapse of time, and the "danger" signal goes out.

The researchers are accumulating data which characterizes the changes in the temperature regime within the capsule, the air-humidity ratio, ventilation, etc.

During the course of the experiment the attendants make notes in a special journal around the clock, sitting at a table in front of a large control panel which carries the signal lamps and instruments.

The condition of the dogs can be evaluated at any instant of time on the basis of the readings of the various pieces of equipment. The doctors and biologists connect the recording instruments for the recording of the physiological functions in accordance with a definite schedule.

A scientific coworker activates an instrument by turning a switch beneath which is the notation "EKG [electrocardiogram] for Strelka." A wide paper tape begins to inch forward, and fine styluses mark out the curve of the cardiac biological current on this tape. Each half hour the number of respiratory cycles and the pulse rate are calculated. One has but to move the lever of an instrument or to turn a switch and complex curves appear, as if by magic. When examined by an experienced eye these curves enable the researcher to arrive at a conclusion regarding the many physiological functions of the animal. All of this will be decoded and converted into a series of numbers which will reveal to the researchers the physiological processes taking place within the live organism.

A special small instrument clicks to indicate that Strelka is moving around. Upon examining the instrument closely through a glass window we see that the sounds are produced by a special little stylus which jumps upward rather violently. As the stylus moves it draws out a vertical line. Here, for instance, the stylus did not come down. This means that the dog has moved forward and away from the center line, lying down in another position. The instrument will show us how much time she spent lying down and when she changed her position.

The living space available for the dogs in the capsule is less than

a meter. The animals are unable to move in their usual fashion here. Under these conditions we can expect the appearance of unfavorable symptoms indicating some disturbance in the animal's organism.

How then do the experimental dogs feel under these conditions?

It turns out that they feel quite good. This is indicated primarily by the autonomic indices. The animals exhibit a good pulse and respiration rate, normal blood pressure, normal body temperature, etc. The biological currents of the muscles, the heart, and the brain differ little from the usual currents recorded prior to the experiment.

The rigid limitations imposed by the living quarters produces a significant change only in the behavior of the dogs. Have you ever seen healthy dogs which spend the greatest part of their time lying down? Probably not, but this is what you will see here.

Animals, when placed in a capsule, most frequently lie on their stomachs. During the day, many of the animals have their paws stretched forward, and they raise their heads (such active lying positions are characteristic of dogs that are not asleep and ready to jump up at any instant).

Occasionally the animals rise and stretch. Some of the dogs subsequently remain standing for some time, whereas others sit or lie down, assuming another position. Sometimes the entire capsule trembles because the animals have not surrendered their usual canine habits and shake themselves.

In other words, the dogs actively reproduce all movements that are possible under the conditions prevailing within the rigid limitations of their quarters. It is clear that these episodic movements and, chiefly, the change of position are employed to prevent possible hemostasia which could occur in the case of pronounced restriction of movement for the dogs.

The animals behave in particularly active fashion immediately prior to feeding time. They move their feet out of impatience and they glance with great interest at the empty food container. Strelka sniffs at the container and Belka, none too sure of herself, reaches out and touches the container with her paw. Pushok, looking at the covers which are in motion during the time that the automatic feeding device is in operation, moves her head from side to side in a strange manner and suddenly begins to bark at the food container as if it were a human being.

All of these reactions are intensified as the automatic feeding device is put into operation. Slowly the open box, empty because all of the food that had been in it has already been eaten, begins to move and this motion is accompanied by the characteristic noise. There is a click and the box is closed, replaced by another box that is filled with food. The dogs withdraw their paws and get ready; their hungry eyes are glued to the ever-expanding slit of the cover, they draw in the tasty aroma through their nostrils, and their sensitive ears react to all sounds. As the box comes into position before the animals, they immediately begin to sink their teeth into this jelly-like food. As you can see, bright and intensive digestive reactions are preserved by the dogs in the capsule, despite the conditions prevailing in this prolonged isolation experiment.

Occasionally, we can observe certain "unethical" forms of behavior. Lowering their snouts to the boxes containing the food, the dogs defend their food containers against the "attacks" of their neighbors, separated by screens. We find them howling, grinding their teeth, and barking at one another in a frenzy. But the scientists are gladdened by this for the following reason. When the animals show such emotional reactions in this small isolated chamber, it indicates that

the dogs feel well.

Day upon day goes by, and the condition of the animals does not worsen. As before, the instruments report the normal course of the basic physiological processes of the experimental animals. As before, they continue to behave well, sometimes actually behaving better than before, and this indicates adaptation. The dogs make no effort to carry out intense movement, they do not gnaw at the instruments, they change position, sleep well, and they "look" at people through the observation window, but they make no effort to stretch out toward these people because they have before them a solid obstacle. The impression is as if they were "cognizant" of what is possible and what is not, and they are now behaving quietly, in accordance with what they have learned, through actual practice, to be possible. All of this can be explained quite easily, since the dogs have undergone preparatory training.

When the signal is given for the conclusion of the experiment, the room is again filled with people. The chamber (capsule) is opened and we can again approach the animals. There is much mutual gladness. The dogs bark, stretch out to reach the hands of the experimenters, and they are very excited. The people are touching them and petting them, but it is time to return to work: Strelka and Belka are called by the laboratory assistant who frees her pets from the wires, a technician pulls off the connecting tube, and the dogs are once again in the hands of the happy experimenter.

Now the dogs are to be examined; x-rays will be made and the blood will be examined. After half an hour, on meeting the laboratory assistant who is carrying the dogs in his arms and asking him how the weight of the animals had changed, we hear that one of the dogs had gained 270 g, and the other 300. "Just like on vacation," says the laboratory assistant happily. Deprived of any possibility of expending energy on movement and finding themselves, at the same time, in a

state of good health, the dogs frequently gain greatly in weight under the conditions of such an experiment.

It was not always thus. Initially, the dogs were removed and were found to be in a poor state of health; there were actually cases in which it was necessary to cut short this complex experiment in order to save the lives of the animals. And if you now give thought to the tremendous work which preceded the establishment of all the necessary conditions in the chamber for the normal vital functions, you cannot help but gain in respect for those people who are capable of achieving this. After all, an experiment of this sort is a dress rehearsal for a flight into the cosmos.

CANINE SPECIALIZATION

Geophysical rockets are also employed in our country, in addition to satellite vehicles, for purposes of carrying out scientific investigations as part of the study of outer space.

Rockets can ascend to altitudes of several hundreds of kilometers. When such ballistic rockets are launched vertically, a state of weightlessness can be produced to last for at least several minutes.

The forward motion of such a rocket is difficult to imagine. Beginning its trajectory at one end of the continent, it can reach the other end within 30 minutes.

There is much that the flight of a geographic rocket and that of a satellite-carrier rocket have in common. In particular, the ascent is identical; therefore, living organisms will be affected in the very same way as those factors which prevail during the active phase of the flight (trajectory). The return of animals and research equipment is, in principle, identical.

However, vertical rocket launchings cannot be recognized as space flight in the full sense of this word, because the flight factors (weightlessness, cosmic and ultraviolet radiation, etc.) are present here

in only very such short intervals of time. But within these few minutes, during which the animals in the rocket find themselves under conditions of weightlessness, it is possible to clarify certain of the features in their reactions and behavior.



Dogs which have been sent into the cosmos in rockets (from left to right): Otvazhnaya, Snezhinka, Malek, Neva, and Belka

Thus many of the rocket produced data are of great practical significance for the flight of the space vehicles. For this reason many medical-biological investigations were carried out during the rocket flights prior to the successful achievement of prolonged flight of animals in outer space.

The launching of animals in ballistic rockets, the latter launched vertically, were begun in 1949 in the USSR. In recent years, rockets attained flight altitudes of more than 450 km.

The following were used as experimental animals during these flights: Snezhinka, Otvazhnaya, Malek, Zhemchuzhnaya, Kozyavka, Pestraya, Pushok, Neva, etc.

There were several people standing around a desk in a small light

study. Their attention was directed at a little dog seated on a chair. It was a small, white, dull-colored dog with long and slightly yellow fur and black button eyes; she was sitting quietly among the people, wagging her tail in friendly fashion, extending her snout to the hands that were petting her. The dog is being measured for length, height, and girth in various positions.

One of those present says "Zhemchuzhnaya, on the basis of her dimensions and behavioral features, can be transferred from the "rocket" dogs to the group for satellite flight."

The dog is taken away and the people gathered here discuss the problem of transferring Zhemchuzhnaya, famous for her rocket flights, to the "satellite" dogs. Will there be any advantage in this change in her profession? What additional work must be done with this dog, etc.?

This minor episode shows that the preparation of the animals for flight in a satellite vehicle differs from the work required for a dog intended for rocket launching. This is understandable and is a result of the specific features involved in flights of satellites and rockets.

As is well known, the flight of a rocket can schematically be divided into three stages. The first stage is the so-called active phase in which the rocket is accelerated to the required velocity. During this period, a living being situated in the capsule will experience acceleration, vibration, noise, as well as all of the other factors that are present in the ascent of a satellite.

The second stage is the so-called passive phase of the trajectory, in which the rocket moves by inertia. During this phase the state of weightlessness comes into being, but lasts only for several minutes.

Finally, the third stage is the return of the rocket to earth. This stage occurs quite quickly — approximately after 8 to 12 minutes after the launch. Here again the animals are affected by acceleration

and other unfavorable factors (because of the ever-increasing friction against the air and the retardation of rocket motion).

Thus animals sent aloft in a rocket experience almost all forms of cosmic disturbances, but for an extremely short time interval.

This explains why dogs intended for rocket flights are, in many respects, examined and trained just as those animals that have been selected as candidates for flight in a satellite vehicle; however, at the same time, the first dogs are not called upon to carry out a number of highly dangerous and difficult procedures involved in the long training period. They are not trained to spend 10 to 15 days at a time in a small-dimension chamber, they are not called upon to learn to eat from an automatic feeding device, etc.

A laboratory assistant brings two white dogs into a large room. In one corner of this room there stands the heavy cone-shaped head portion of the rocket. We can look into this section through a hatch which covers tightly the access to the center of the compartment. The dogs are placed in oval-shaped cradles lined in soft felt.

The animals have long ago become familiar with this procedure. One has but slightly to press against the back of an animal, and it will lie down, quietly observing the actions of the human being. The animals are fastened to the cradle by means of special straps. The laboratory assistant places and fastens the cradle inside the rocket compartment. The hatch is closed and it becomes dark inside. Within an hour the experiment is concluded and the dogs are removed from the capsule, walked, and returned to the vivarium. And this is how it goes, day in, day out.

Thus the animals are trained to withstand immobility without pain under conditions that are close to those they will experience in the rocket.

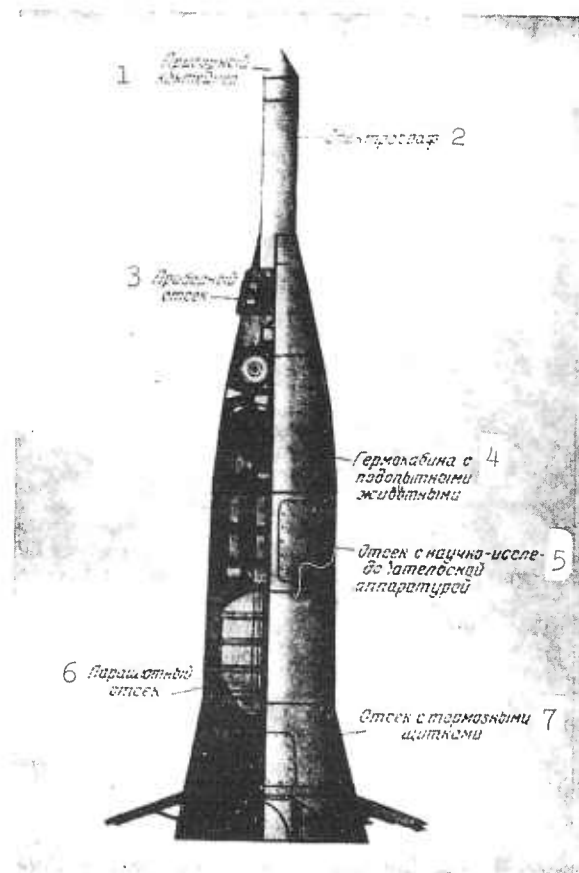
The "rocket" dogs are, of course, trained to withstand accelerations

(on a centrifuge), to withstand vibrations (on a vibration stand), and to be able to deal with the recording instruments required for the physiological indicators by means of instruments that are especially adapted for rockets; in addition, conditioned reflexes are developed in the animals, etc. Sometimes, the animals must be "familiarized" with simpler objects. For example, the dogs are placed in front of a small installation in which a motion-picture projector has been mounted. If the animals are not trained in advance to the noise of this new device, it will produce intense orientation reactions in the animals and possibly even fright, as result of which the physiological indicators might change. When the projector is first turned on the animals look around feverishly; since they are tied down, they press even closer to the cradle in which they are lying. Pal'ma begins to strain at her leash. Seconds pass, the projector hums, it does the animals no harm, and then gradually the dogs are pacified. The next time, when noise is made by the projector, the animals only raise their ears and turn their heads.

Such preliminary familiarization of the animals with various factors prevailing in a flight substantially reduce the number of unexpected occurrences which are unavoidable in any new investigational undertaking.

FLIGHTS

ROCKET TRAVEL



Cross-section of capsule for geophysical rocket.
 1) Instrument container; 2) spectrograph; 3) instrument compartment; 4) air-tight capsule with experimental animals; 5) compartment with scientific-research equipment; 6) parachute compartment; 7) compartment with deceleration shields.

The rocket is standing on its launching pad. Otvazhnaya and Snezhinka are sitting in a special compartment. The dogs have been

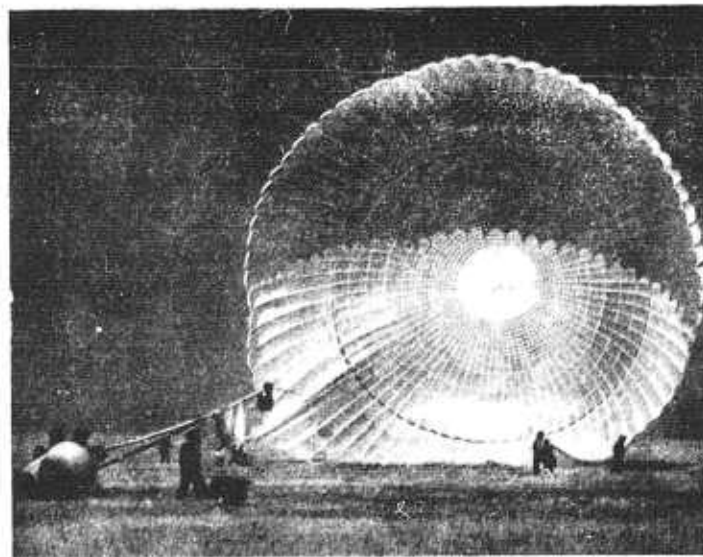
tied into their cradles with particular care this time. They are relatively quiet. There is nothing unusual about this; the animals have had an opportunity to grow accustomed to the conditions prevailing during a launching and they have already spent several days here.

Now somewhere beneath the dogs the engines have started and the noise and vibration from the engines have spread through the steel frame of the rocket. This situation could not be reproduced precisely under laboratory conditions, and although the experimental dogs have grown accustomed to the variety of and frequently unexpected disturbances, if the animals were not tied down and had not, prior to this, been subjected to the many vicissitudes of their changing fate, they would begin to strain at their leashes. Now, however, they develop only an intense passive-defensive reaction and a pronounced orienting reaction.

The rocket begins to gain speed. A motion-picture camera will be directed at the animals continuously throughout the flight. Upon landing, the film will be developed and the scientists will be able to analyze the behavior of the animals by a careful and attentive examination of the individual frames. What is it that the scientists will see on this unique film?

The first stage. The dogs feel the ever-increasing force of gravity. Snezhinka strains to keep her head up. At first she is able to do this, despite the increasing G forces. We can see how she is able to overcome the ever-increasing force of gravity for several seconds by jerking her head slightly upward, at the same time greatly straining the muscles in her neck, chest, and back. But soon the dogs are no longer strong enough and their heads begin to roll from side to side; the over-all picture reminds one of the phenomena observed in the case of pronounced shaking.

Otvazhnaya behaves somewhat differently, since she immediately presses her head against her cradle - this is easier. This animal has flown rockets several times before and it therefore finds the most convenient position more rapidly.



Capsule touch-down

The differences in behavior between Otvazhnaya and Snezhinka indicate that dogs that have already experienced rocket flight adapt more easily to the negative conditions that they encounter.

But let us continue our observations. Suddenly both of the dogs simultaneously and very quickly toss their heads and pull them all the way back. At the same instant the hands on the clock next to the animals indicate the exact time at which the state of weightlessness sets in on the rocket. The transition from great G forces to this unusual state alters the tonus of the neck musculature of the dogs. The external manifestation of this change is seen in this involuntary movement of the head.

These facts, insignificant at first glance, confirm the theoretical hypothesis of a number of Soviet scientists regarding the effect that

weightlessness has on the tonus of the musculature. These facts provided the impetus for the subsequent statement and experimental solution of many interesting problems. This explains why in subsequent rocket launchings it was possible to study the changes in the tonus of various animal muscle groups, and why much attention was devoted to the development of the methods of myography (the recording of the electrical currents of the muscles).

But let us return to the experimental dogs. They are now in a state of weightlessness and their bodies are free to move to any point in the capsule without support. However, Otvazhnaya and Snezhinka have not moved from their places: after all, the dogs have been tied down.

The instruments, specially adapted for work under conditions of acceleration and weightlessness, record the various physiological functions of the animals' organisms.

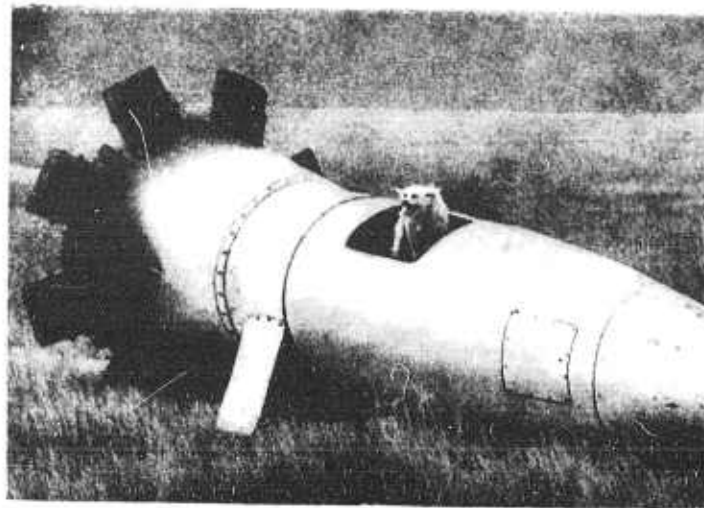
Initially (during the acceleration) the number of respiratory cycles executed by the experimental dogs increase to 30 - 60. Then as the state of weightlessness set in, the respiration rate gradually diminished and approached its initial level.

The pulse rate, in comparison to the initial rate, increased by 200 - 100 beats [sic] during the acceleration period. The blood pressure increased by 45 to 100 mm Hg.

Detailed information on the respiratory rate of the animals during the active phase of the flight and under conditions of weightlessness are stored in thick rolls of film. The decoding of these curves, and the determination on the basis of these curves of the characteristics of respiration, pulse, the electrocardiogram, etc., is an exacting and laborious procedure. This work falls to the lot of the laboratory assistants, under the direction of the medical scientific coworkers.

Pronounced changes in autonomic processes are typical for the active phase of the rocket-flight trajectory.

However, let us return to the flight of Otvazhnaya and Snezhinka. Judging from the behavior of the animals, they begin to feel better upon entry into a state of weightlessness after the acceleration period. Phlegmatic Otvazhnaya is quiet and active Snezhinka turns her head. A nut which probably was loosened as a result of the vibrations floats before the dogs' snouts. In its weightless condition, the nut now bumps into various objects, easily moving through the air. Snezhinka follows this flying nut with her eyes, as she would a fly, turning her head and straining to sniff at it. A ray of sun shines through the observation window of the rocket and falls upon the dogs, the instruments, and the clock. Tiny granules of moving dust become visible in the light. Snezhinka shakes herself, turns her head, and keeps her eye on the passing sunbeam.



Otvazhnaya's safe return

Under conditions of weightlessness the behavior of the dogs and

the nature of their response reactions to external stimuli forces one to assume that there are no significant changes either in the course of the basic functions nor in the animals' behavior if the dogs find themselves in a state of weightlessness for short periods of time.

After an additional lapse of time the dogs suddenly stop moving. Apparently the force of gravity has again begun to make its presence felt. But at this instant the animals disappear from our field of view. This is a result of the fact that the descent has now begun. As the front end of the rocket begins to penetrate into the denser layers of the atmosphere, the G forces are great and change in direction; under these conditions, many of the instruments cease to function.

During the first flights the rocket's motion through the dense layers of the atmosphere had not been adequately stabilized. The dogs were sometimes found to be lying on their backs and their legs turned upward, or they were found to be in what seemed a suspended position: their rear paws up, and their heads down. After a little while the forward end of the rocket begins to move at a somewhat different angle and the direction of the G forces with respect to the bodies of the animals again changes. Thus unlike the G forces experienced during the ascent, i.e., acting in a single direction, the animals find themselves in a more difficult situation on descent: not only are they affected by pronounced acceleration, but the G forces are variable in terms of direction. It is a good thing that the dogs are tightly bound. You can imagine what would happen to them if, with their greatly increased weight, they were to strike against the walls of the capsule and the many instruments mounted there.

When the animals were removed from the nose of the rocket, they had completely recovered from the disturbances that they had experienced. A careful examination of the animals showed only insignificant

hemorrhagic effusion into the sclera of the eyes, into the mucous-lined cavity of the mouth, into the skin of the auricles, and edema of the ophthalmic region. This represents all of the injuries sustained, for example, by Otvazhnaya and Snezhinka during the period in which the front end of the rocket moved through the dense layers of the atmosphere and during the period of descent.

In one of the first flights the dog Pestraya sustained a number of injuries. It is true, of course, that she recovered quickly and appeared healthy within three months, but latent disturbances of the central nervous system could still be noted for a long time.

During the initial stage of the work it sometimes happened that the animals sustained rather serious injuries.

The training of the animals for flights aboard satellite vehicles required a great number of scientific experiments involving the vertical flight of rockets.

Just as Otvazhnaya and Snezhinka, Belyanka, Pestraya, etc., were sent into the cosmos and returned safely to earth.

Investigations with a rocket capsule that was not hermetically sealed and involving the utilization of a special space suit had to be carried out in order to resolve a number of problems.

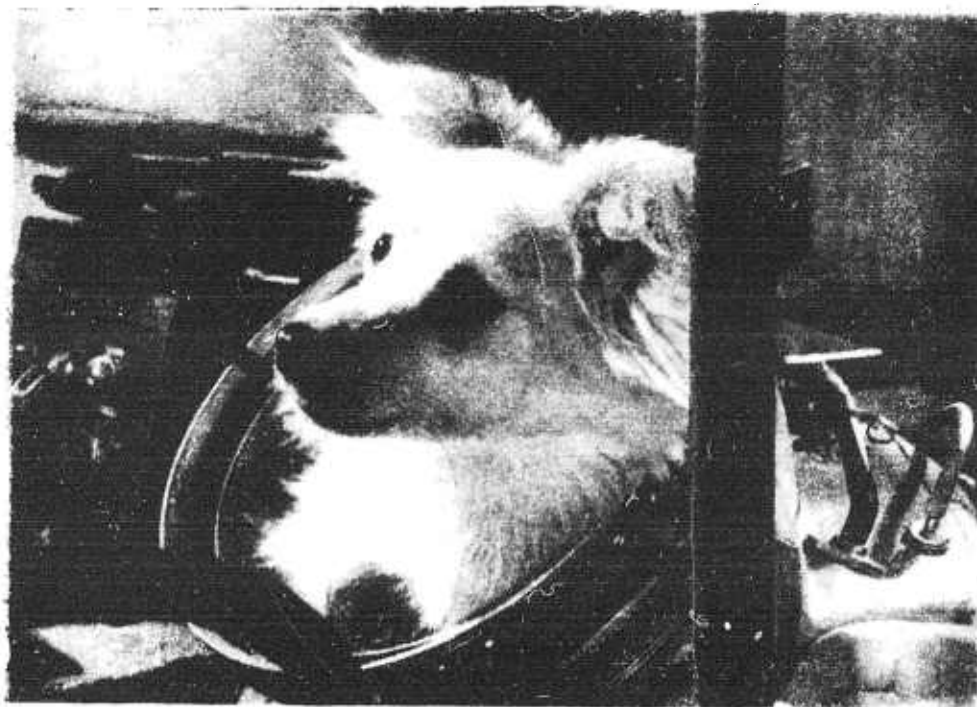
Kosyavka, Al'bina, Malyshka, and Linda were sent to an altitude of 110 km in such a capsule, i.e., a capsule that was not hermetically sealed.

The space suit is a form of clothing made of several layers of rubberized fabric that serves as an air-tight sack with closed "sleeves" for the animal's paws and is equipped with a transparent plexiglas spherical helmet, which made reliable provision for the vital activities of the dogs at this tremendous altitude. A pressure adequate to prevent the phenomenon of anoxia was maintained beneath

the space suit; the temperature of the air in the space suit changed within insignificant limits.

Many of the dogs that had flown in rockets have been in outer space more than once. The majority of these dogs continue to serve space medicine to the present time: they are being used and ready for future experiments. Others, having earned a well-deserved and extensive rest, continue to reside in the vivarium. The scientific workers continue to keep under observation those animals that have been in outer space.

ADDITIONAL ROCKET PASSENGERS



Kozyavka in her space suit, but without her helmet

You are looking at a familiar photograph, taken in 1959: the dogs Otvazhnaya, Malek, and between them another rocket passenger — a rabbit.

The rocket flight with the rabbit produced the first documentary

photographs that clearly reveal the processes taking place in the eye muscle of a rabbit with the onset of weightlessness.

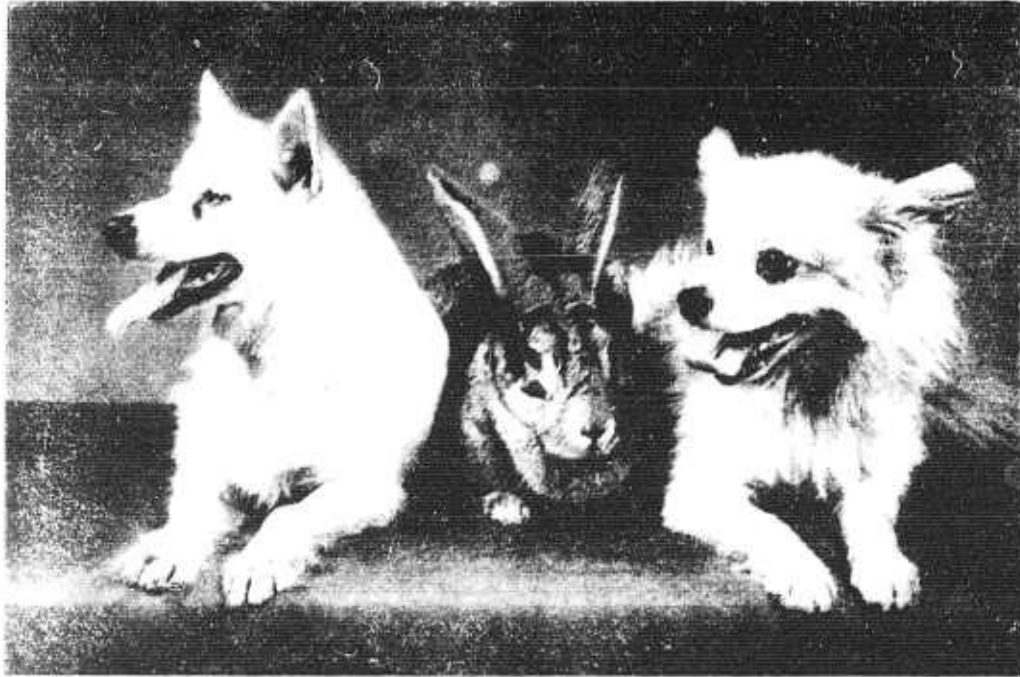
It is a particularly great research success when a scientist is able to isolate a simple phenomenon from among a series of complex phenomena, and to show clearly and pinpoint those changes which were brought about by specific disturbances. This was how the effect that the state of weightlessness exerts on the tonus of the muscles was determined.

Let us take an ordinary rabbit and tie it down to a special cradle so that it is completely deprived of its ability to move; in this case particular attention must be devoted to the reliable immobilization of the head. The strapped rabbit lies submissively and looks around quietly.

Together with the cradle, the rabbit is turned on its side and we see that the rabbit's eyeball is deflected and turned down. This is a phenomena that is common to all animals. The turning of the rabbit on its right side changes the nerve impulse originating in the otolithic apparatus in the inner ear and causes a reflex change in the tonus of the eye muscles.

The tonus of the muscles is most easily understood as being the tension of muscles without changing the length and cross-sectional diameter of the muscles. The role of the tonus consists in the maintenance of that favorable background which is required for the functioning of the muscles. With a change in the tonus of the appropriate eye muscles, the eyeball shifts upward; in the opposite case, the eyeball moves down.

This is a biologically advantageous phenomenon. Because of this mechanism the eyes of a rabbit are maintained in their initial position, regardless of any changes in the position of the body, thus



Malek, Otvazhnaya, and the rabbit

allowing the animal to maintain the stability of its original field of view under its normal conditions of existence, i.e., this mechanism promotes good spatial orientation. Indeed, imagine what would happen if an animal's eyes were constantly shifting while it was running; it is clear that the rabbit would simply be unable to run in the right direction.

This movement of the eyes was employed to clarify the problem of the effect produced by changes in the force of gravity on the state of muscle tonus. Will there be any change in the rabbit's eye movement during the rocket flight, during acceleration, and during the state of weightlessness? And if there will be a change, how pronounced? The rabbit is held in a plaster-of-paris bath in order to keep immobile in the rocket capsule. The gypsum keeps the rabbit

immobile. This is done in order to eliminate any effect on the tonus of the eye musculature as a result of the turning of the head and neck. Some 6 cm above the animal's eye we can see the shimmering of the objective of a motion-picture camera. The rocket will be launched in several seconds, but the camera is already grinding away: the animal's pupil must also be recorded on film at a time during which the rabbit is still on the ground and is normal in weight.

We are now looking at a long motion-picture film which shows the movement of the rabbit's eyes. We measure the space between the iris and the cornea of the eye. Initially all of the spaces are identical. Then we see that the eyeball gradually begins to deflect downward. This deflection proceeds continuously. Finally it reaches a whole 2 mm (from the standpoint of a small muscle, this is very much). By the markings on the film we can see that the weight of the rabbit in the rocket had increased by a factor of six-and-a-half during this period. This explains this remarkable deep "dropping" of the eyes.

Suddenly the eyeball quickly shifts upward. This "jump" of the eyeball coincides with the onset of the state of weightlessness. The eyeball quickly returns to its initial position, and we soon record an upward deflection of the eye, again some 2 mm. The eyeball holds this position for some 5 minutes, i.e., the entire period during which the rocket finds itself in a state of weightlessness.

All of these seemingly insignificant changes are quite revealing. For example, the eyeball can shift upward only if the tonus of the corresponding muscle diminishes and, conversely, the eyeball can shift downward only if the tonus increases. These facts demonstrated the relationship between a change in muscle tonus and the effect of terrestrial gravitation. The tonus increases during acceleration and

diminishes in the state of weightlessness; this is the basic conclusion resulting from the experiments that were examined.

Soviet and foreign authors, on the basis of relatively few experiments and many theoretical hypotheses, speak about the possible change in the conventional structure of movement under conditions of weightlessness. Some investigators note insignificant deviations from the norm which have no effect on the activity of a pilot - his movements are sufficiently precise and are executed with the usual speed. Others speak of deflections of the hand upward and to the right under conditions of weightlessness. Many facts on uncoordinated movements were gathered during the study of the motor activity of animals under circumstances of reduced weight.

Certain theoretical hypotheses serve as the basis for such opinions. Briefly they can be outlined as follows.

The force of terrestrial gravitation is somehow intertwined with each motor act. This is understandable; the force of terrestrial gravitation has participated in the formation of movement for the millions of years during which live organisms developed; movement could not possibly have originated and continue without this force. This explains why any motor act assumes the necessary prior condition of terrestrial gravitation - and it also explains the assumption of certain changes in the functioning of the musculature in the case in which there is no gravitational attraction.

Which systems of an animal organism, however, can be subjected to the effect of weightlessness?

The process of movement under terrestrial conditions is a function primarily of the muscles themselves. Muscles are bundles of living fibers of unique construction. Their chief property is the capacity to contract and relax. The force of muscle contraction is

determined by the quality and number of muscle fibers, their tonus, etc.; but muscle fibers are not bothered by either a change in weight or by the total absence of weight; muscles will function as usual even under these conditions.

The coordination of individual muscle contractions into a complete and useful action is accomplished with the participation of the nervous system as a whole, and with the cerebral cortex in particular. Perhaps weightlessness affects the nervous system, and the brain, producing an effect on the muscles through the latter?

The control of movement according to the teachings of I.P. Pavlov assumes two processes; first of all, the reflection of each completed motor act in the brain and in the receptor nerve cells; secondly it assumes the formation of impulses in the cerebral cortex which subsequently (through the system of nerve trunks) proceed to definite and particular muscles in order to produce a new movement. These two processes are interrelated. Each new movement of an animal comes about in conjunction with and on the basis of the preceding movement.

Thus it must be assumed that in conditions of weightlessness both the mechanisms which provide for the reflection of the preceding movement in the cerebral cortex as well as the systems which provide for the process of originating a new movement will suffer. How then are we to determine the functioning of these mechanisms and by what means can we find out whether or not they are associated with the action of the force of gravity?

First of all, do the properties of the so-called proprioceptors change in conditions of weightlessness? Situated at the surface and deep within the layers of the muscles, these nerve endings react to all changes taking place within the muscles, tendons, and ligaments. An animal has but to bend its paw, move its head, etc., and the stimulated

proprioceptors send impulses to the brain reflecting the picture of the movement that has occurred. It can hardly be assumed that the proprioceptors can be the cause of disrupted motor acts in a state of weightlessness. Their work is a function primarily of the intramuscular relationships which prevail at any given instant in an organism and need undergo no significant change under conditions of weightlessness.

The so-called otolithic apparatus plays an important role, in addition to the above-enumerated points, in the formation and course of motor acts and coordination of movements. It has been demonstrated that it is precisely this apparatus which plays the chief role in those deviations from the normal state which take place in motor apparatus under conditions of weightlessness.

We know that the functions of the otolithic apparatus under terrestrial conditions are directly associated with the work of the muscles and it has a direct relationship to the tonus of the muscles. Situated at the bony base of the inner ear, the otolithic apparatus is hidden deep within the skull. In this small enclosed cavity the bottom is lined with sensitive nerve cells which have the thinnest of nerve processes; they are covered by the otoliths - small grains and crystals of calcium carbonate and calcium phosphate which, because of their weight, press against the nerve endings. As the animal changes the position of its head, the grains shift and the force of the otolithic pressure against the nerve cells changes. As a result the nerve cells are stimulated, which results in nerve impulses whose force is directly proportional to the magnitude of the otolithic pressure. These impulses are transmitted to the central nervous system and indicate changes in the spatial position of the body.

It might be thought that in a state of weightlessness, when the otoliths are no longer affected by the force of gravity, their pressure

against the nerve endings would cease and the manner in which the spatial position of the body is indicated would be changed. Thus there appear the contractions of certain muscles and, conversely, the relaxation of other muscles under conditions that are unusual from a terrestrial standpoint. The changes which determine the disruption of an animal's movements (as well as, apparently, those of a human being) under conditions of weightlessness involve the otolithic apparatus, the muscle tonus, and the musculature.

Regarding the positions and reactions of animals under conditions of weightlessness, we can speak of yet another type of rocket passenger as an example.

Experimental rats have served the goals of science for more than a hundred and fifty years. This small white animal with pink paws and smooth fur is a thoroughly and completely studied biological subject. This circumstance each time facilitates its utilization for new purposes. And here we have another animal. It very much resembles a rat but is smaller in size. This is the white laboratory mouse which is also very frequently used for various biological research projects.

At the moment a group of selected rats and mice is confronted with the prospect of participating in experiments directed at a study of the nature of motion in a state of increased gravitation and weightlessness.

The motor acts of animals under conditions of weightlessness, for various degrees of freedom, is not only of interest from the theoretical point of view, but from the practical standpoint as well. During the course of preparing for the flight of a human being into outer space, it was important to determine how the state of weightlessness affects the coordination of an animal's movement during a relatively prolonged flight.

The behavior of dogs in a state of weightlessness was studied both for the case in which they were tightly fastened to their cradles as well as for the case in which they had the freedom to move slightly (movements to the front and to the side, approximately 10 - 15 cm). It was particularly interesting to observe the motor reactions under conditions of free movement. At this time this is possible only in experiments with small animals - rats and mice.

We have before us two small containers made of plexiglas. There are rats in one container, and the mice are in the other. The transparent walls enable us to observe the behavior of the animals and to record this behavior on motion-picture film.

The film is subsequently subjected to careful study. Individual behavioral details of the animals are noted, as are the configuration and the changes in the form of the motor acts; in addition, the data which characterize the rate of movement on the part of the rat, etc., are calculated.

The very first frames in the film show clearly the unusual behavior of the rats. There is a gradual increase in the inhibition of their movements, their paws are spread far apart, and their backs are not bent as much. The animal drops its head ever lower and, finally, places it on the bottom of the container. You have apparently already guessed that we are looking at the time period during which the container was subjected to conditions of increased gravitation. These film frames characterize the behavior of rats during the ever-increasing acceleration forces.

The weight of the rat increases so much that its usual rate of movement initially drops sharply, and then the small animal stops moving entirely. Apparently the muscle strength of the animal is inadequate to overcome the acceleration forces it experiences.

Several seconds pass. Suddenly the rat quickly tears away from the floor. For some fractions of a second she "hangs" somewhere in the middle of the container. The unaccustomed absence of points of support produces excited movement and these, in turn, foster new motor acts. And now the rat begins to move in disordered fashion in the container. She turns about her own axis, and she flies into a corner and spins there much like a top. Then she executes a somersault on the floor of the container. The animal's tail behaves as an independent lever which straightens out and bends at some angle. The paws are spread far apart. All of these are phenomena which affect the rat during weightlessness. The mice behave in approximately the same way.

How can we explain this behavior of the rats? We will present only one of the most probable theoretical assumptions.

Under accustomed terrestrial conditions all animals experience a change in tension in various muscle groups with a change in the spatial position of their bodies. The nerve impulses to the muscles originate in various organs and systems (vision, hearing, the organ of balance, etc.) and from these the impulses proceed to the muscles. This takes place automatically, i.e., reflexes which provide the required body position. The sensation of "up" and "down" is of tremendous importance in these reflexes, and this in turn is directly associated with terrestrial gravitation — weight. The indicated reflex reactions which determine the position of the body in space have been referred to as postural reflexes or position reflexes.

The rats experience the disturbance of the acceleration forces and subsequently the state of weightlessness already exhibiting similar inherited reflexes. In the case of acceleration forces, in connection with the ever-increasing weight of the body, the flow of

nerve impulses from the cerebral cortex changes, and this results in changes in the above-indicated position reflexes.

Changes in afferentia continue during weightlessness when conventional stimuli cease to act. The kinesthetic and vestibular stimuli weaken or disappear entirely, i.e., the stimuli which arise during muscular motion or which proceed from the otolithic apparatus (and this affects the state of the muscle tonus), and the sensitive (afferent) systems and postural reflexes are disrupted.

As a result the rat, on losing weight, loses the sensation of "down," and remains seemingly without any vertical support. She has lost her accustomed point of support, the tactile and other sensations in her paws and tail have been changed, as has the impulse proceeding from the vestibular apparatus. Only vision continues to serve the animal normally. However, vision is not in a position to correct the chaos of unaccustomed sensations, particularly at first. It is no wonder that after having lost their points of support the animals exhibit violent motor activity, somehow seeking the required position spontaneously.

Initially these attempts produce the opposite results. Each movement fosters the following movement which is also extremely intensive in force, amplitude, and rate. The movements of the rat become uncoordinated. It seems as if the situation is extremely difficult and there is no way of telling how the animal will extricate itself from this situation. But let us not be hasty.

Let us continue our analysis of the film frames, examining even more attentively the movements of the rats.

We note (approximately after 40 - 45 seconds after the transition into a state of weightlessness) that the rate of the animal's movements no longer increases. This is good. After some more time the

movments become slower and smoother.

The figures show this clearly. Prior to the 20th second the rat moved ever more rapidly. An additional 17 seconds (beginning with the 20th to the 37th) the rate of the animal's motion ceases to increase: it turns at a rate of approximately two-and-a-half turns per second. After that the speed of rotation gradually diminishes to one turn per second. This same quantitative relationship is observed in a comparison of the figures which characterize the rates of the motor reactions in other rats.

What factors are responsible for this? The first factor which enters our mind is that the rats have become tired as a result of their intense somersaulting, and this produced the reduction in the rate of their movement.

However, it is doubtful that this is the case; after all, only slightly more than a minute passed and during this time such an animal as a rat will not become tired. Moreover, during the entire period of intensive motion the rat did not have to overcome weight and, consequently, her expenditure of energy was lower than under normal conditions.

Comparing many facts, the experimenters prove that the setting in of smooth motor responses, the reduction in the number of these reactions, and the appearance of individual relatively coordinated motor acts all indicate the adaptation of the animals to the conditions of weightlessness. Apparently, in the case of the rats a number of mechanisms which provided the rats with some normalization of their motor acts began to form. It is clear that the dominant factor in such adaptation is the organ of vision - the powerful stream of impulses originating in the optic analyzer brings an ever-increasing number of reflexes under its control. It is, of course, unfortunate

that the state of weightlessness cannot be prolonged in order to examine how the animals will continue to behave. But let us remember that these tests were being conducted prior to the launching of the artificial satellites and space vehicles and, consequently, the study of the state of weightlessness for longer periods of time was still a matter for the future.

The experiments and the analyses of the derived facts made it possible to arrive at a conclusion regarding the differences between individual animals in their ability to adapt to the conditions of weightlessness. It turned out that in the case of various rats smoothness and delay in motion set in at various times.

Thus as a result of the described preliminary experiments it was possible to assume that man will adapt himself rather rapidly to the conditions of weightlessness, will learn to move in the proper directions, and to execute purposeful coordinated motor acts. This is, in all probability, the decisive factor. Definitive answers to these questions will be possible only after the first manned space flights. During the period being described there were only a small number of observations conducted of the movements of a human being under conditions close to that of weightlessness, during the flight of a jet aircraft; in addition, there were short-term observations of the state of weightlessness (about a minute) during special training sessions for human beings. However, all of these data are sufficient to permit us to speak of the adaptability of the organism to conditions of weightlessness.

THE FIRST "COSMONAUT"

And now the animals are completely ready for flight; we have before us a telegram whose contents can be expressed in the single phrase "We are waiting." This means that everything is ready for the launching

of a rocket satellite into outer space.

In September 1957 all of the advantages and shortcomings of various dogs were discussed and considered as part of the final selection of the animals to make the flight into the cosmos. One after another, various scientific workers made their reports on the features of the physiological reactions of each animal to rotation on the centrifuge, the effect of vibrations, etc. They recalled which dogs received good grades during training for prolonged seating in a capsule, they again examined the diaries which describe the behavior of the various dogs, and they read the data of the veterinary examination.

A white dog with black symmetric spots on her somewhat droopy ears receives the most favorable evaluation. Her fur is smooth, her tail is short, and her paws are fine and straight. You have, evidently, already guessed that her name is Layka. Layka, as all of the other experimental dogs, is a mongrel. She was given her name because she had the habit of barking particularly frequently, and her barking was both demanding and loud.

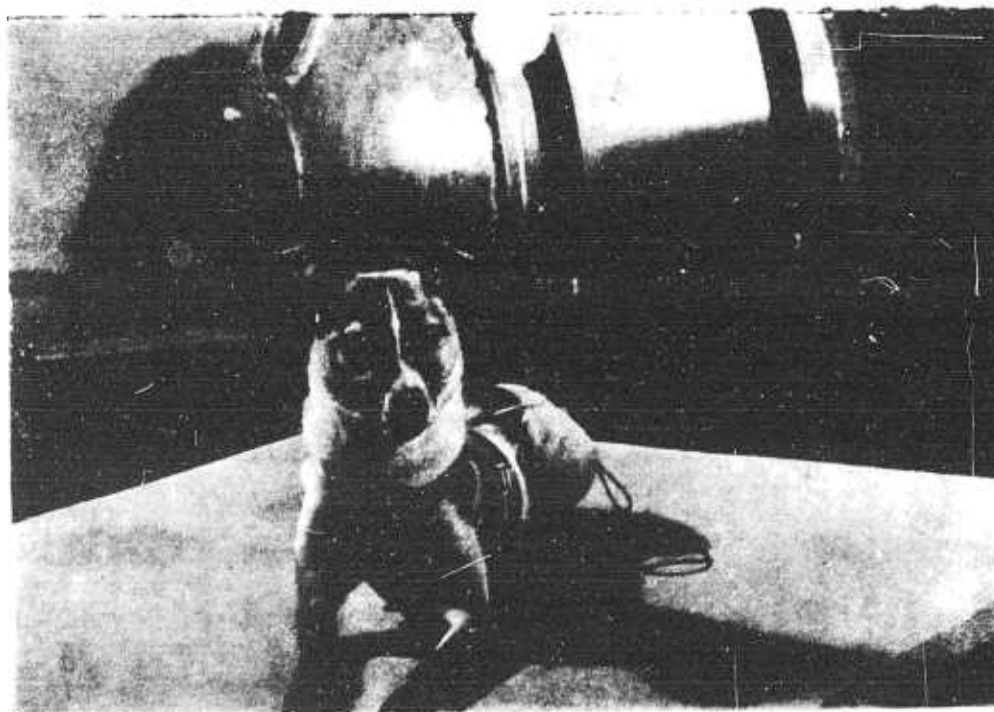
Thus it fell precisely to this animal's fate to become the first "cosmonaut."

The morning of the 31st of October in 1957 was cheerful and there was a nip in the fall air.

After her walk, at 10:00 hours Layka is carefully dressed in the laboratory. The animal's skin is rubbed down with a weak solution of alcohol; her fur is combed with a special comb. The areas around the electrode leads are smeared with iodine and powdered with a streptocide. Layka behaves as usual: she is quiet, but she is active at the same time. At 12:00 the dog is dressed into her harness, and at 14:00 she is fastened inside the capsule.

The open capsule resembles a semi-oval elongated nest with high

walls. The cork floor is heated and there is an opening for the sanitation tank in the floor. At the front we see the automatic feeding device. The walls of the capsule are covered with soft material which resembles swanskin. At the bottom, along the sides, and on top there are a great variety of clever devices which will provide for the animal's vital functions. Here we also have all of the recording equipment. Now Layka has only to wait, and she will have to wait a long time.



Layka in the laboratory

Now Layka's capsule is covered with the bell-shaped top portion. All of the equipment designed to record the various physiological processes is checked out. It is necessary to determine once more that all of the instrument readings are correct, and the instruments must be tested in conjunction with the telemetry system, i.e., a check

must be carried out on how the instrument readings will be transmitted over distance.

Moreover, the reliability of all facilities providing for the normal vital functions of the animal must be checked, as must the hermetic sealing of the capsule; in addition, the fail-proof supply of oxygen into the capsule must be checked out, as must the removal of carbon dioxide from the capsule. Finally, the functioning of the automatic feeding device must be checked out. All of this takes up several hours.

Finally everything checks out and the container with the animal is mounted inside the forward end of the rocket.

It is 1 A.M. in the night 1 November. Layka sleeps in her impenetrable capsule, rolled up, as usual, into a ball; the staff of doctors and engineers begins the last stage in the preparation for the flight - the integrated testing of the equipment. Again all of the instruments are tested individually, one after the other, and as a unit. Now everything is ready.

We can still catch a glimpse of Layka, lying quietly, through the observation window before the engines of the rocket carrier are started. She is standing and looking around her carefully, and she starts to shake. Having shaken herself and sat down, she presses her body against the wall of the capsule. The animal notices the human face at the thick observation window and immediately becomes tense and lifts her head. Her eyes are fixed on the window and they follow any movement on the part of the human face behind the observation window. The dog is quiet and she executes, as usual, some 16 - 37 respiratory cycles per minute; the frequency of her cardiac contractions is also normal - 68 to 120 per minute.

The automatic feeding device is soon actuated. On hearing the

accustomed click of the device, Layka stands and begins, at first, to look carefully at the cover of the device, and then she starts eating with a hearty appetite.

What awaits this experimental animal? Now Layka seems to be an integral part of a complex mechanism which is to rise into outer space and encircle the earth for a long period of time.

Unlike the first Soviet artificial satellite of the earth, the second satellite (weighing 508.3 kg) consisted of the last stage of the rocket, and this is extremely important, since the experiment with the satellite demonstrated that the rocket carrier is much more easily observed than the satellite itself. Prior to the launch, a special shielding cone was placed over the instruments in the forward portion of the satellite, thus hiding these instruments from the eyes of an observer. However, as soon as the satellite rocket was injected into orbit, this cone was separated. The equipment designed to study space phenomena was now open and ready for action: there was the instrument mounted on a special frame, which was designed to study solar radiation; the spherically shaped container with the radio transmitters and other equipment; and finally the hermetically sealed capsule with the experimental animal.

The second satellite carried radiotelemetric equipment. The artificial satellite transmitted signals for a period of seven days in accordance with its schedule of scientific investigations, and only after the conclusion of this period did the radiotransmitters and the on-board radiotelemetry equipment cease to function.

Everything had been calculated and provided for in advance.

It was the early morning of 3 November. It was still quite a while before dawn, but people were already awake and working intensively. Soon the signal will be given and the rocket will climb into

the heavens.

Schematically the flight of the space vehicle carrying Layka can be divided into two stages.

The first stage is the so-called active phase of the trajectory. This is the segment of the course in which the engines of the rocket carrier are in operation. In order to place a satellite into orbit colossal energy is required, and this energy must be capable of imparting the required acceleration to a heavy body in order to enable the latter to attain the first cosmic velocity (orbital velocity).

During this period of time Layka will be subjected to the effects of great acceleration forces, much like the animals that were sent aloft in rockets.

The second phase is the phase during which the satellite is in orbit and during which it moves in cosmic space at the velocity that has been imparted to it; there is complete silence and there is a total absence of any visual stimuli. Throughout this entire period of time the dog is in a state of weightlessness.

The signal for launching was given early on the morning of 3 November. People observed how the rocket lifted off and sliced through the sky from behind special blinds and bunkers. We can see an ascending strip of light in the sky; then this strip of light turns into a glowing point.

Only two minutes have passed and the velocity of the rocket increased so rapidly that the weight of all the items in the rocket increased by a factor of four-and-a-half. The minutes pass and the acceleration forces continue to increase ... this is the difficult part of the satellite flight from the biological standpoint. The rocket frame was also subjected to great vibrations and the noise was unusually pronounced.

The dog was not at all used to all of these phenomena. Her heart began beating rapidly, contracting more than 260 times per minute. This means that immediately after the launch the frequency of cardiac contractions increases in comparison with the initial by a factor of approximately three. Subsequently the frequency of the heart beat diminished. An analysis of the electrocardiogram failed to show any significant disruption in the activity of the dog's heart muscle. Only a typical pattern of sinus tachycardia was observed, i.e., a rapid heart beat.

With increasing acceleration forces the respiratory rate of the dog also underwent a pronounced increase. At the very highest acceleration forces it exceeded the initial magnitude approximately by a factor in excess of four.

However, all of these phenomena did not last for too long a period of time; after all, the active phase of the flight trajectory does not last very long. No motor disturbances were observed in the dog during this period. Perhaps we can speak only of a certain muscle tenseness on the part of the dog.

All of these cited data indicate that the animal withstood quite well the flight of the satellite, from the launch to the entry of the satellite into orbit. This conclusion is confirmed also by a comparison of the derived material with the results of the previous laboratory experiments and the data obtained in the launching of dogs in ballistic rockets.

There is a final powerful push by the rocket engines and the satellite begins to move by inertia. Experiencing no friction it moves in orbit at the colossal velocity of about 8 km per second.

Suddenly an unusual quiet envelopes the capsule with the animal. All vibrations disappear. There is nothing external that can now dis-

turb Layka. Her body becomes light and gradually the dog's weight diminishes to zero.

For a long time the effect of a prolonged stay in a state of weightlessness on the organism was a mystery. A number of optimistic hypotheses were presented in the theoretical plan, but they could not be verified experimentally under terrestrial conditions. The launchings of the ballistic rockets were also unable to make possible any more than a short-term state of weightlessness.

Therefore it is difficult to overestimate the great significance of Layka's flight. After all, this is the first flight which produced direct answers to the question as to whether living beings could exist under conditions of space flight. Without this answer it would have been impossible to speak of such flights by a man.

What then was it that happened to this living being in orbital flight, which for the first time experienced the prolonged effect of weightlessness.

On sensing its great distance from the earth the radio installation aboard the satellite began its continuous transmission of signals into the ether. These signals were received. Let us familiarize ourselves with the decoded information regarding the flow of physiological processes in the animal, this information received from the first scientific space laboratory.

The physiological processes of this first cosmic traveler underwent substantial change during the active phase of the flight during which the acceleration forces acted upon her, while under conditions of weightlessness these processes returned to normal. The frequency of cardiac contractions diminishes. The animal begins to breathe easier, etc. It was also possible to determine that despite the fact that Layka was restricted in her movements, her motion retained its smooth-

ness and continuity.

The animal lived. It breathed, her heart continued beating, and her brain functioned. This was remarkable. It means that it is possible to create a small terrestrial island in outer space on which a highly organized animal can live successfully.

These may only have been the first preliminary results, but they served as firm ground for the great steps that science would take in man's effort to conquer the infinite reaches of the universe.

The data obtained in this flight were of basic significance from the standpoint of space medicine and biology.

These data showed for the first time that the prolonged effect of weightlessness does not disrupt the basic physiological functions of an animal. These materials also demonstrated that the basic engineering and medical-biological goals with which science had been confronted prior to the launching of the second artificial satellite of the earth had been chosen and attained in proper fashion.

THEY RETURNED

Three years have passed. It is now August 1960.

Again the director finds a telegram on his table. Again we have the selection of the cream of the crop of trained dogs. Among these dogs we find Zhemchuzhnaya and Mushka, and everyone's favorite Lisichka; we also find the little grey dog Marsianka, Belka, active Pchelka, phlegmatic Il'va and playful Strelka... all of the dogs are healthy and all have undergone the required tests, receiving outstanding evaluations.

The dogs are washed, combed, fed well, and they are frequently walked. They are happy and play up to people; their behavior is active but disciplined.

A great quantity of scientific material characterizing their

cardiac activity, respiration, gaseous interchange, and blood has been collected about each one of these animals. Many nerve phenomena have been studied, the behavior and its features have been described, and in a number of cases conditioned reflexes have been developed; in addition, the type of higher nervous activity has been determined. The materials have been processed and evaluated: we find graphs and tables and photographs. These are data which characterize the normal reactions of an animal. They make it possible for us to arrive at a judgement regarding the deviations and disruptions which are possible both during and after a flight into outer space. Each dog has been provided with its own passport, i.e., a small booklet in which, just as in an actual passport, there is a photograph of the dog - the future cosmonaut.

Belka and Strelka are the animals which were selected. Belka has nonsymmetrical almost yellow spots on her ears and sides, and she is less than a half meter in length; she is only thirty centimeters tall. She weighs five-and-a-half kilograms. This is a cheerful and "businesslike" dog.

Strelka is a little larger in size, i.e., both longer and taller, and her weight is the same as that of Belka. This dog has an elongated snout and a pretty design of dark-brown spots. Similar colored spots are also scattered over Strelka's sides and back.

Belka and Strelka patiently go through all of the preparations for the flight. They spend long and quiet hours in the capsule, waiting for the completion of the check-out procedure of the great variety of equipment. Now there are a great many more instruments than in 1957, but many of the instruments have been improved and reduced in size. An outstanding feature of the capsule in which the animals are to fly is the fact that it has been fitted out just as if the capsule were to

carry a human being: the same equipment as would provide for the vital activity of a human being, heat control is carried out in the same manner, etc. Only it will not be a man that will fly in this capsule, but dogs.

The container in which the dogs sit is a catapult cart [sled]. This dictates the unique shape of the capsule. It provides for a position of the center of gravity at which the catapulted container with the animals, on returning to earth, will fly in a proper and stable position.

Both of the dogs are dressed in their complete experimental outfit - a red and green suit - and they are looking out of the capsule. People are particularly attentive to the dogs today. Even the director of the laboratory checks on their condition and well-being and to see that they eat and drink well.

During the last few days and weeks Belka and Strelka have found themselves the beneficiaries of many privileges, and this is fully justified. It is extremely important to keep the animals under such conditions prior to the flight so that their organisms would be capable of withstanding the great variety of unfavorable flight factors. If the animal is not prepared for this in sufficient time, the functional reserves of its organism will be reduced even prior to the flight and the dog will not be able to resist the forthcoming difficulties as well.

The capsule in which the experimental animals are sitting is made of a light metal. Much that we find here is familiar: the cradles in which the dogs have been placed, the automatic feeding device, the sanitation device, the ventilation system, etc. The capsule has a removable cover. Mirrors and the lamps of the illumination system are installed in this cover, i.e., all of the devices required for purposes of television.

The rocket is scheduled to be launched during the middle of the summer day of 19th of August. It is hot and we can see how the transparent streams of hot air are rising. The entire area is hot.

However, the reliable heat insulation of the capsule and its artificial cooling protect the animals against the heat. The air temperature in the capsule is about 20°C. This is extremely important, since the dogs (we spoke about this earlier) do not take heat as well as they do cold. The specially developed heat-regulation installation mounted in the second satellite vehicle functions automatically and maintains a constant temperature in the capsule. Even if the satellite is bathed in the hot burning rays of the sun during the flight, and even if the satellite's skin is heated during the launch, the temperature inside the capsule will not rise.

The system which controls the gas composition of the air and its pressure is no less reliable. The sensing elements and special sensors report how the chemical substance is performing its function of absorbing the carbon dioxide and water vapors, and in what quantities oxygen is being fed in.

And now in outer space, at an altitude in excess of 300 km, Belka and Strelka are circling the earth over and over again. It is simply unbelievable that each such revolution around our planet takes only an hour and a half. Again and again they find themselves over that side of our planet on which our Motherland is located and at that time all of the space observatories of the Soviet Union receive reports from the space vehicle. These data are instantly transmitted to special centers which evaluate and process all of the incoming material.

It is now clear that the dogs feel well during their orbital flight. The television images as well as special motion sensors indicate their normal behavior.

In a state of weightlessness the animals' paws do not always find support, but this apparently does not "disturb" the cosmonaut dogs; after all, they have been trained and accustomed to their leashes and the small dimensions of the capsule. Belka, suspended by chains, looks at her partner through the screen and seems to be barking at her. In any event the television makes it possible for us to record the characteristic movements of the snout and open mouth of this white dog.

Later on, on the ground, the data which characterize the pulse, the electrocardiogram, respiration, blood pressure, and other physiological functions of these two four-legged cosmonauts will be analyzed. Each motor response of the dogs (thanks to the exact time markings on the television frames) will be compared with the changes in the physiological processes. The careful recording of the dogs' behavior will make possible the correct evaluation of the effect of various flight factors.

The satellite vehicle - the pride of Soviet science - is flying through bottomless space. The automatic mechanisms, the chemical power sources, and the solar batteries are functioning faultlessly. The exact and faultlessly functioning instruments correctly orient the satellite. The radio equipment aboard the satellite quickly transmits information by means of radio and television. The radio equipment reports that the vital functions of the cosmonaut dogs are being carried out normally within the continuously moving vehicle.

There was some alarm in the laboratory. Everyone was convinced that Belka and Strelka would return to earth; however, there was much concern. Not one of the beings that had spent several hours in outer space had failed to return. No one believed that they would fail to return, yet everyone was overwhelmed by the burning desire to have Belka and Strelka, so dear and familiar to us, back on our Soviet soil.



Belka's descendants

The sixteenth revolution, the seventeenth revolution of the satellite vehicle above the earth. During the eighteenth revolution the command for descent was given. The vehicle obediently prepared for the descent phase.

Descent is a particularly important time. Not a single even insignificant error can be permitted here, because such an error can result in the destruction of the satellite. For several seconds the velocity

of the vehicle is greatly reduced. This means that everything must be calculated with extreme precision at this time.

The instrument compartment is separated from the capsule in the descent trajectory. Then the capsule is decelerated even further as it enters the dense layers of the atmosphere. At this point the velocity of the capsule must be calculated exactly, since otherwise it may burn up like a meteorite which passes through the atmosphere of the earth.

The capsule is now at an altitude of 7 km above the earth. At this point the container with the animals separates from the capsule and it rapidly approaches the ground. There is a thump and the container is on the ground. The container has landed in an ordinary kolkhoz field. Signals are continuously being sent into the ether enabling us quickly to find the container. This is not difficult; after all, the capsule and the container have landed in the assigned region.

Cars speed to the landing point. Everyone is concerned about the condition in which the dogs will be found. No one doubts the fact that the dogs will be found alive. This is confirmed after several minutes.

And in the laboratory, gathered around the loudspeaker and holding their breath, the entire staff that worked on the preparation and training of the animals is listening to the TASS report. However, the news that Belka and Strelka were alive and that they had landed at the preset time and in the precisely calculated point had long since been received by the scientists in the form of a congratulatory telegram.

There was an air of unaccustomed gladness and light-heartedness in the laboratory. The scientists congratulated each other. The safe landing of the dogs was a triumph of the peaceful efforts of the Soviet people; how could one help but to be glad at this achievement of our [Soviet] engineers and doctors.

The animals showed no injuries at all upon being taken out of the



Zvezdochka

container. This shows that the descent trajectory was faultlessly chosen and calculated. The acceleration forces which were generated as the vehicle entered the dense layers of the atmosphere did not exceed the magnitudes that had been calculated as permissible for live organisms and the container with the dogs did not overheat; the shock forces were not too great and the catapulting [ejection] was properly handled ... this can be said of all the elements of the ascent, the orbit, and the descent. Everything had functioned precisely as had been planned.

After the second satellite vehicle carrying live beings had returned to earth (20 August 1960), the flight of a man into outer space became a practical possibility. However, it was necessary to check and recheck the functioning of all the systems installed in the vehicle; these systems are designed to provide for the normal conditions of man's vital activities. It was important to obtain additional information on the effect of weightlessness and the transition from the state of weightlessness to the state in which the acceleration forces take effect, as well as to obtain more information on the effect of possible cosmic radiation on living beings.

In the time from the safe landing of Belka and Strelka to the historically unique flight of Yu.A. Gagarin aboard the vehicle "Vostok-1" a third satellite space vehicle (with the experimental dogs Pchelka and Mushka), the fourth satellite space vehicle (with Chernushka) and, finally, the fifth satellite space (with Zvezdochka) were launched.

The launching of the fifth satellite vehicle on 25 March 1961 was the last control experiment before the manned flight into outer space. The vehicle landed in its exact landing area. Zvezdochka withstood the flight well. It is noteworthy that Yu.A. Gagarin, who would soon be confronted with a trip along the same cosmic route, accompanied this dog to the cosmodrome. Yuriy Alekseyevich wished the dog a safe and successful trip with all the warmth he would express to any dear one. Also worthy of note is the enthusiasm, one might almost say reverence, which Yu. A. Gagarin felt for the power of our engineering capabilities at the time of the launching of the fifth satellite vehicle, when "the rocket, literally a living thinking being, in meditation, trembling slightly for a second, suddenly finds itself above the earth and unattainable, leaving behind a turbulent wake of flame as it disappears

from the field of view with a flourish, marking a bright trail across the sky."

MANNED FLIGHTS

PROBLEMS OF SELECTION AND TRAINING

Man has dreamed of flight into outer space since time immemorial. However, it has never been more than a dream — a daring but fantastic dream. It is only at the present time that we have seen this dream turn into a difficult but practical problem. Manned flight into the cosmos has now become a matter of actual fact.

It is the 12th of April in the year 1961. On this day Yuriy Alekseyevich Gagarin, a simple Soviet man, full of energy and the joy of life, knowledgeable and capable, took his position in the capsule of a space vehicle that had been set up for an unprecedented flight. The satellite vehicle "Vostok-1" climbed to a fabulous altitude and revolved around our light blue planet. This was a triumph of Soviet science. A wonder had been achieved and its creators were Soviet people — scientists, workers, and engineers.

The kosmonaut [astronaut] landed safely in a predesignated region of our Motherland. Taking his first steps after the flight over the freshly spring-plowed collective-farm fields and breathing in the familiar aroma, he was once again heartened by the earth and knew that he had brought great gladness to the entire Soviet people.

And thus the assignment had been carried out. A man had spent time in outer space and had returned to earth.

Naturally, there arises the question as to why precisely this individual had been selected, and there is the question as to the indicators that were employed as the basis for this selection, and

how this and other astronauts had been trained for the flight.

Let us try to imagine how we would have to organize the selection and training of a human being for space flights if we were to start this program at the present time on the basis of the achievements of contemporary medical science and based on the data which were derived as a result of the first space flights with experimental animals.

Bear in mind that it is your task to select the individuals who will participate in the first flight into outer space.

The selection of individuals to be trained for a specific profession which requires definite physical and psychological characteristics on the part of the human being (such as the profession of a pilot, submariner, etc.) is a complex matter even if the specifics of this work are known, and if we have the characteristics and knowledge which are necessary for the particular profession involved.

How then are we to approach the selection of astronauts, when there is still so much that we do not know. Where are we to begin? It is quite clear that in the solution of this problem we must take into consideration, first of all, the experience gained in the selection of pilots and, secondly, the features of cosmic flight; the nature of the activity and the conditions encountered during the astronaut's stay in the capsule of a space vehicle, i.e., those results which can be anticipated from a human being as a result of the organism being disturbed by flight factors.

However, prior to the present time, despite the important data derived after the flights of Yu.A. Gagarin and G.S. Titov, science did not yet have at its disposal sufficiently complete information regarding the influence exerted by many space-flight factors on the human organism in the case of a prolonged flight. It is characteristic that in the majority of cases the hypotheses regarding certain

changes in the physiological processes under conditions of space flight are based on theory and to a lesser extent on experimental data. There is no practical experience involving prolonged manned flights, and the simulation of the conditions of such prolonged flights under conditions of a ground experiment is, by no means, always possible.

It was possible to resolve many of the problems through the flights of animals into the cosmos. Particularly much was gained from the first manned flights into outer space. However, there is much that is not yet clear. For example, scientists, for all intents and purposes, know very little about the effect that a prolonged (more than a full day) exposure to the state of weightlessness exerts on the human organism, and this applies equally to the transition from the state of weightlessness to the conditions that prevail in the event of acceleration forces. It can only be assumed that no mortal danger exists. The influence of cosmic radiation has not yet been subjected to a thorough study. We can speak only tentatively about the psychological reactions of an astronaut under the conditions prevailing during a prolonged flight. Finally, the simultaneous effect of the entire complex of space factors on the organism is virtually unknown.

On what basis are we then to make our selection of the astronaut? Physical strength and endurance, knowledge of engineering, a fast mind, rapidity of response, or thorough theoretical training. Perhaps we can make our selection on the basis of a deep desire to fly into the cosmos, daring, the ability to preserve good spirits despite prolonged solitude, etc.? How is one to reveal the apparently latent qualities and what is the best approach for the training of such individuals? All of these problems make the selection procedure

an extremely difficult matter.

However, there is quite a bit that we do know about this area. For example, experience in the selection of pilot crews has given us much information. It is also clear that space flights, and particularly the first flights, will call upon the astronaut to mobilize all of his physical and moral strength. In addition to the psychological stresses that are associated with the risk, the uniqueness, and the complexity of the situation, the human being will experience the effect of acceleration, noise, and vibration. He will find himself in a small capsule in which his mobility will be significantly restricted. The astronaut will experience discomfort as a result of having to wear special forms of clothing for prolonged periods of time, etc.

These, apparently, are the basic initial medical requirements which will have to be imposed on the state of health of the future astronauts. Taking these factors into consideration, we will have to arrange for their examination, special training, and exercise and testing prior to the flight into the cosmos.

One more stipulation has still to be made. All of the considerations regarding the selection and training of a human being will be regarded as pertaining to the first space flights. In subsequent manned space flights much will be determined and much will be refined; gradually all of the details that await man on such travels will become clear, and we will also learn which new requirements must be imposed. There is no doubt that better methods of selecting and training future astronauts will be found.

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Let us think of the wide and light corridors and wards of a clinic. Here we find nurses and doctors in white tunics on duty, and there are a number of small studies (rooms). But the unusual part is

that there are no patients. We have healthy people before us, and not simply healthy, but absolutely healthy, cheerful, happy people. You have already probably guessed that examinations are being conducted here of those individuals who have expressed their readiness and willingness to become astronauts.

Let us go into a cozy room across whose floor a large carpet has been spread. These individuals sit in this room in armchairs during their free time.

An active medium-sized individual is telling two of his friends with great animation and gestures how he was able to maneuver his airplane out of a difficult situation during a flight through clouds. His audience was able, through questions, to see that his knowledge of flying was great. Another group, in the next room, is engaged in a serious conversation on the advantages and shortcomings of a new type of airplane.

If you were to listen to the conversations of these people gathered here, you would automatically find your attention drawn to the fact that the subject matter is similar in each case. Apparently, representatives of the flying profession are being examined here. If we were to turn for an explanation to the director of this unusual clinic, he would confirm our assumption. Indeed, the kosmonauts (astronauts) are selected from among pilots, and moreover from among excellent pilots.

It goes without saying that not all pilots expressing the desire to become astronauts are invited to visit our imaginary clinic. The preliminary selection is carried out by doctors specially assigned to airfields, and the number of rejections during this selection process proved to be quite great.

What is the exact reason for having to select these future as-

tronauts from among pilots?

The answer to this question lies in the fact that the first astronaut must be an individual who, in addition to good health, must exhibit strong will, fast reactions, and the capacity to make instantaneous decisions and carry them out immediately under the great stresses and pressures prevailing during a flight. The first astronaut must be an individual who is familiar with the ocean of air, and the effect of the factors that are close to those that he is likely to encounter during a space flight. We can anticipate that individuals exhibiting all of these properties will be found among fighter pilots whose professional activity, on the one hand, calls for excellent health, and on the other hand, creates in the individual such volitional and physical characteristics as are required of an astronaut. It is for this reason that we find pilots in this clinic that we are describing.

But what of the future? When it comes time to fly to near-by celestial bodies rather than in an orbit around the earth, the crew of a space vehicle will, apparently, consist not of one but of many people and then there will be not only pilots but representatives of many other professions as well. This is true, and in this case the requirements imposed on an individual's health and psychological characteristics will have been completely defined; however, once again not everyone will be able to participate in such a flight.

All this is true, but why are healthy people — pilots — kept in a clinic? There can be no doubt that among these individuals we are hardly likely to find any who are sick. As a matter of fact, we are not likely to encounter any who are sick, in the usual sense of the word. But this is not enough. First of all, we must be completely sure regarding the complete health of this future astronaut; after

all, the complex clinical examination which all the pilots must pass (the so-called medical flight commission) does not always reveal minor latent shortcomings in the state of an individual's health. Consequently, it becomes necessary to set up particularly careful examinations and it is precisely for this reason that these individuals have been gathered at the clinic.

Secondly, it is not sufficient to be satisfied that this astronaut candidate is healthy. It is also important to determine all of the features of his organism's reactions which will appear under conditions of various forms of activity associated with significant physical and psychological stress. All of this can best be done under the conditions prevailing in the clinic.

There is no need to describe the conventional medical research which will, apparently, also be conducted here. We will dwell in detail only on those special methods which are used in the selection and training of our future astronauts.

RESERVE POTENTIALS

Let us go somewhat further down this light corridor of the clinic. To the right and to the left we see glass doors and the floor is covered with some synthetic material which deadens the sound of our footsteps.

Let us open up one of the doors and enter a relatively small but light room. We are immediately caught by the long table of somewhat unusual shape in the center of the room. The top of the table can be turned and it can also be fixed in place at any angle to the horizontal plane. Along the walls we see various instruments; there is the familiar electrocardiograph and the electroencephalograph, an instrument that is almost mandatory for each and every laboratory. There is also an unfamiliar instrument that is referred to as an oxyhemograph,

i.e., an instrument which makes it possible to record the degree to which the blood is saturated with oxygen; in addition, there are other devices to record the physiological functions of an organism. All of this equipment, variously shaped and rather beautiful, involuntarily calls forth our respect.

In order to understand the purpose of this laboratory, let us go way into the past. We are in a stadium, and a young man has just completed an extremely exhausting race. Tired, immediately after the finish he lies down on the grass; however, after some 2-3 minutes he gets up. But what do we have here? This young man, glowing with health and having just completed a difficult distance, blanches, and falls in a faint.

The explanation for this is quite simple; the youth is actually healthy and will yet have an opportunity to break racing records. He has simply not been careful in this case, i.e., he interrupted his work sharply, lay down, and immediately got up.

The situation is the following. In the case of intense muscular activity there is a pronounced increase in muscular metabolism. In order to ensure the intake of the required quantity of oxygen and to provide for the removal of the products of oxidation, the blood vessels of functional muscles open up completely and the heart, under great pressure, forces an ever-increasing mass of blood through these vessels. When athletes lie down upon completion of a race, the activity of the heart returns to normal rather quickly (the pulse rate diminishes, and the intensity of cardiac contractions is reduced). The vessels of the muscles return to normal much more slowly, they are still expanded, and if the athlete were to get up during this time, the blood would accumulate in these vessels, the flow of blood to the brain would be disrupted, and as a result anemia of the brain would

set in, and this produces the fainting. It is for this reason that athletes are advised to slow down gradually, not stopping short, but rather to continue running even after the completion of a long distance. Thus the cardiovascular system gradually returns to its former state.

Here is yet another example: a file of athletes freezes in response to the command "attention." A certain time passes, but no command of "at ease" or "forward march" is given. Suddenly the rank is disrupted and one of the athletes loses consciousness. Such cases are not rare and have been described in the literature that is devoted particularly to the military basic training of combat units.

Here the factor responsible for the faint was the draining of the blood from the brain. In placing the body "at attention" we find that as a result of gravity the blood flows into the lower sections of the body, the muscles are motionless, and cannot assist in the normal blood circulation. Nevertheless, all people do not faint. This phenomenon is observed only in individuals who do not have a completely perfect mechanism for the nervous regulation of the cardiovascular system. Such regulation is provided by the corresponding changes in heart rhythm, vascular tonus, etc.

At the same time, we also observe that the cardiovascular system of a human being can adapt to the various conditions of activity, since its reserve potential to provide for muscle work is quite great.

Thus, for example, given a healthy mature male the heart generally ejects approximately 4 liters of blood per minute into the blood system (the so-called per-minute volume of the heart), and in the case of extreme stresses of the muscular system the per-minute volume of the heart of a trained individual may attain the tremendous quantity of 35 to 37 liters, i.e., an increase by a factor of 9. In this

case the pulse rate climbs to 170-180 beats per minute.

The reader may ask how, despite the interesting nature of what has been said here, this affects a manned flight into outer space?

Let us recall the reactions of animals under the action of acceleration forces. During a period of increasing acceleration forces it was shown clearly that the cardiovascular system experiences a great load, and during a flight into outer space there will be the effect of other factors on this system in addition to the forces of acceleration.

Many scientists have expressed the theoretical hypothesis that immediately after a prolonged stay under conditions of weightlessness a man will not be able to withstand physical stress and acceleration forces as well as he had been able to prior to the state of weightlessness. Indeed, under conditions of weightlessness the heart muscle is called upon to perform much less work than usual in order to provide for the flow of blood to the vessels, because there is no need to overcome the weight of the column of liquid (blood, in this case). Possibly the tonus of the blood vessels may change (there is, after all, some validity to the assumption that people with a large heart must feel better under conditions of weightlessness). All of this leads to a situation in which the heart muscle somehow is found to be "out of shape" and if a man, subsequent to this, rapidly makes the transition to conditions under which the sensation of weight suddenly reappears (particularly if the weight is greater than normal [the effect of acceleration forces]), the same heart muscle which formerly was able to cope with these increased requirements will now no longer be able to stand up under these stresses and there will be a pronounced expansion of the heart and decompensation of cardiac activity.

It should immediately be stipulated that all of these assumptions,

although rather convincing, must actually be checked under conditions of flight. It is quite evident that a trained organism, in which the reserve potentials of the cardiovascular system are greater, will better be able to cope with these difficulties. It is for this reason that the functional state and reserve potentials of the cardiovascular system must be the subject of particular attention and be rigorously evaluated. This is further the reason why it is necessary to select individuals with the best cardiovascular systems for space flights.

It will be necessary to conduct not only the conventional and commonly employed medical tests of the cardiovascular system involving measured physical load (kneebends, running in place, etc.) as part of the examinations of individuals expressing the desire to become astronauts, but other research methods as well, i.e., methods which will make it possible to characterize more completely the state of the cardiovascular system and to bring out all of its latent defects.

Both here and in the USA the above-described rotating table is employed as part of the examination of pilots.

Here we have an astronaut candidate tightly bound with special straps to the top of this table; at this point he experiences no pain nor unpleasant sensations. A doctor and a laboratory assistant are keeping track of instrument readings indicating the state of the cardiovascular system of the candidate. Thus the initial background is established, i.e., the data which characterize the cardiovascular system of this individual under the normal conditions of its activity. After this the table is made to rotate and is fixed in place at some, larger or smaller, angle so that the individual's head is below his legs. Some time is permitted to pass, the doctors observe the instrument readings carefully, check on the condition of the examinee, and note is taken of the fact that the blood begins to flow into the head,

causing the face to redden. There is also a change in the nature of cardiac activity, the magnitude of arterial pressure, etc.

Observing subsequently how the individual reacts to this unusual position of the body and how quickly and regularly the nature of his cardiac activity changes, we are able to obtain data regarding the state of his cardiovascular system and the condition of his compensatory mechanisms.

Comparing the results of this test with the data obtained in other laboratories, we can arrive at a correct conclusion regarding the suitability of the candidate to execute a space flight.

The human organism has great reserve potentials in other areas as well.

Indeed, who does not know, for example, that individuals are able to withstand both extreme cold and tropical heat?

The temperature is 68° below zero and there is an icy oncoming wind. However, the man on the low dogsled seems not to feel the cold. Occasionally he jumps off the sled and runs alongside. Great resistance to cold is characteristic not only of the permanent inhabitants of the North. The conquerors of the North Pole were individuals who, prior to this, lived in a variety of climates and they withstood these extreme air temperatures without harm. A human being maintains a constant body temperature; if the body temperature falls below 25° or rises above 43° the results are, as a rule, fatal. A stay under conditions of low temperature is, in the case of a human being, accompanied by the actuation of a number of physiological mechanisms which provide for the maintenance of constant body temperature while, at the same time, maintaining the normal flow of physiological processes. For example, a narrowing of the cutaneous blood vessels is observed and as a result the blood is forced out deep within the

tissue, as far as possible from the cold air, thus making possible the preservation of heat within the organism. Perspiration ceases entirely and there is a change in the nature of the metabolic processes.

There is an increase in the oxidation processes in the tissues and this results in an increase of heat generation, thus consequently enhancing the maintenance of a normal body temperature.

Increased muscle activity also produces greater heat generation. It is for this reason that it is so important to move much and intensively when it is cold, i.e., to perform physical work.

Thus the human organism has itself many weapons with which successfully to combat cold. If, however, we add external means such as warm clothing, the utilization of dehydrated greases, special clothing, etc., then we can say that under natural conditions there are no temperatures on our planet so low that a human being could not adapt to them.

And what of high temperatures? Here we can also speak of the extraordinarily high adaptability of the organism.

The scorching rays of the sun, burning sand, a lack of water and vegetation. But even here, across deserts and burned-out plains, man moves and lives. In addition to local inhabitants we can also meet people from the middle latitudes and even the Far North. These individuals are engaged in the construction of irrigation canals in this unbearable heat, and they work with machinery made so hot by the sun during the day that it does not cool off at night.

Given high temperatures for the external medium the removal of heat liberated by the organism becomes difficult and the constancy of body temperature must be preserved. Naturally, processes take place within the organism that are approximately the opposite of those which are observed under conditions of extremely low air tem-

peratures; everything is directed at the removal of this excessive heat.

The cutaneous blood vessels expand. The sweat glands begin the pronounced secretion of sweat. The skin becomes wet. The evaporation of the moisture from the surface of the skin does much to remove heat and this process is also enhanced by more rapid breathing. The metabolic processes under these conditions proceed much less actively than is usual and this results in a reduction in heat generation.

Thus people can live and work actively both in the Far North and in Antarctica at temperatures of 60-70° below zero, as well as in the South at temperatures of 40-50° above zero.

Such amazing adaptability on the part of the human being to the unfavorable factors of the external medium, which may prevail for prolonged periods of time, can be observed in cases other than his gradual acclimatization to these factors; an individual is also able to withstand brief and sudden negative disturbances within a rather wide range. Here we must speak not of the adaptability but of the resistance to these factors of the external medium.

Let us also dwell in some detail on certain of the physiological reactions (and of these there are many) which enable (assist) an individual to offset the effect of unfavorable factors.

Let us assume that an individual finds himself under conditions in which the quantity of oxygen in the air has been reduced substantially and he is faced with death as a result of hypoxemia (a reduction in the quantity of oxygen in the blood) and in response the heart begins to contract more frequently and the so-called per-minute volume of the heart increases; in addition, the breathing becomes more rapid. As a result a greater quantity of blood per unit

time is passed through the lungs and the exchange of gases in the lungs (the liberation of carbon dioxide from the blood and the saturation of the blood with oxygen) is improved. Finally, the mass of circulating blood is increased. Consequently, a greater quantity of blood flows to the tissues per unit time. All of this will, in some way, offset the shortage of oxygen in the surrounding atmosphere.

Thus the resistance of the organism with respect to the unfavorable factors of the external medium varies in various people. In selecting and training astronauts it is important to determine the individual features in these reactions and to determine the reserve potentials of the organism.

ACCELERATION FORCES

We are looking at a small round-shaped building in which we see a row of windows situated in the upper part of the wall. This enclosure contains the familiar centrifuge.

A scientific coworker seats a man into the couch of the centrifuge and carefully checks the fastening of the special sensors which receive and transmit to instruments which record the biopotentials of the cerebral cortex (an electroencephalogram), of the heart muscle (an electrocardiogram), and of certain skeletal muscles (an electromyogram); in addition he checks the recording accuracy for blood pressure, respiration, etc. The engineers once again check to see whether everything is in order in all of the complex recording equipment. The command is given. Rotation begins.

What does the individual in the couch feel? What changes in physiological processes are recorded by these sensitive instruments?

As soon as an acceleration force of 2 g is reached the weight of the individual's body increases noticeably. With increasing acceleration forces (to 3-4 g) this sensation becomes even more in-

tense; the overpowering force forces the head down and into the shoulders. Movement is possible only with great difficulty. Then as the acceleration forces increase there appears a pronounced pulling sensation in the chest. The feet and shins seem to be increased in size and sometimes the gastrocnemius (muscle) becomes cramped. Blood drains out of the head and there is an impairment of vision. If the forces of acceleration continue to increase loss of consciousness will set in.

What is to be seen on the tapes of the recording instruments? The respiration curve shows initially that there is an increase in the frequency of respiration, and then respiration becomes irregular (prolonged, slow and difficult inhalation, fast and forced exhalation). We frequently see prolonged delays in the respiratory cycle during the middle of the inhalation process.

The blood pressure in the upper part of the body drops, and in the blood vessels situated below the level of the heart blood pressure increases. The amplitude of the electrocardiogram peaks diminishes. The extent to which the blood is saturated with oxygen is diminished. Corresponding changes can be seen on the electroencephalogram.

All of the above-indicated phenomena occur only if the effect of the acceleration forces is continued for a relatively long period of time and if they are directed from the head to the feet.

How a man is able to withstand the effect of acceleration forces is a direct function of the magnitude, duration, and direction of these forces with respect to the axis of the body.

The individual features of the organism also play a great role.

We distinguish the so-called longitudinal acceleration forces (acting in the direction from the head to the feet and from the feet to the head) and the lateral forces whose action is directed perpen-

dicularly to the vertical axis of the body (from the chest to the back, from left to right and vice versa). When the human organism experiences acceleration forces in the direction from the head to the feet, the organs situated in the body cavities (the liver, the heart, etc.), are shifted under the influence of mechanical forces. As a result, there may be temporary disruptions of the functioning of these organs. If the acceleration forces act in the opposite direction (from the feet to the head), then the organs in the abdominal cavity will press against the diaphragm as a result of inertia and this makes respiration and cardiac activity difficult.

Of the liquid media in the organism, blood shifts most readily under the influence of acceleration forces, since on passing through the major blood vessels it represents a large column of liquid. The acceleration forces bring about a redistribution of blood and its flow to and away from the head depending on the direction of the inertial forces.

The sequence of phenomena developing within the circulatory system during a period of acceleration forces directed from the head to the legs will be approximately the following (in this case the blood accumulates in the lower part of the body, primarily in the abdominal cavity and in the legs). The inflow of blood to the heart from below through the veins will be difficult and the shifting of blood away from the head will be facilitated. There will be a reduction in the quantity of blood ejected by the heart. A consequence of all of this is the substantial drop in blood pressure within the skull and this is followed by anemia of the brain. The supply of blood to the vitally important centers of the brain is impaired and consequently these centers will experience a shortage of oxygen (hypoxia). The retina of the eye is particularly sensitive to hypoxia.

Therefore, when the blood pressure at these points drops vision is quickly impaired and the individual suffers a so-called "blackout" (everything goes dark before his eyes). If the drop in pressure continues, loss of consciousness may result.

The earliest external indication of disruption in the activity of the brain is a change in the bioelectrical activity of the brain (the electroencephalogram) and the appearance of visual disturbances. If an electroencephalogram record is being maintained during the action of the centrifugal forces, and this is a step that is always taken during experiments on the centrifuge, then the experimenter can see the approaching danger prior to the appearance of visual disturbances and can stop the rotation in adequate time.

The forces acting in the opposite direction — from the legs to the head — produce opposite changes in the supply of blood to the brain. In this case, the blood flows to the head, the pressure in the brain vessels increases, and effusion of blood into the retina of the eye is possible. It is interesting to note that in the case of such acceleration forces everything seems to be tinted red in color. This phenomenon is known as a "redout." The duration of the acceleration forces also plays an important role. If the acceleration forces last for a short period of time, i.e., lasting for a fraction of a second, they can be withstood significantly better and this is understandable, because during such a short interval of time no significant shifting of the blood can take place, since in order to overcome the inertia of the blood a certain amount of time is necessary. If, however, the acceleration forces are made to exert their effect for a significant period of time, they will produce pronounced changes even if the acceleration forces are smaller in magnitude. A great acceleration force can be withstood by an organism only if the force is

applied for no longer than a fraction of a second. And conversely, a prolonged period of acceleration can be withstood satisfactorily if the force of acceleration is comparatively small.

With increasing magnitude of acceleration forces, directed from the legs to the head (or with increasing duration of acceleration forces), the blood increases in its flow to the face and the individual experiences a pulsating headache ("it seems as if his brain is being torn apart"). It feels as if the eyes are bulging out of their sockets and there is a sensation of sand beneath the lids; at this time everything seems tinted in red. With a substantial acceleration-force magnitude consciousness becomes blurred. What is the appearance of an individual experiencing the effect of such acceleration forces? His face is red and puffy, filled with blood, and the blood vessels stand out on his nose and cheeks, the eyelids are swollen, and the eyes are tearing. An analysis of the electrocardiogram would have shown a significant change. The frequency of cardiac contractions has been reduced (bradycardia), and the blood pressure in the carotid artery is increased.

Acceleration forces acting from the chest to the back and reverse are withstood substantially easier than longitudinal forces. This is understandable because their effect on the blood-circulation system is not great, since a human being has no major blood vessels directed in the lateral plane; consequently, in the case of acceleration forces there can be no redistribution of blood. It is true, however, that even in this case there are a number of unpleasant phenomena, but substantially greater acceleration-force magnitudes are required for these to set in.

When acceleration forces act in the direction from the chest to the back inhalation becomes difficult as a result of the compression

of the chest and abdominal cavities. There is pain in the epigastrium and behind the breastbone. The pulse rate quickens, but moderately; blood pressure rises. During the active phase of the flight of a space vehicle (take-off) and during deceleration in the dense layers of the atmosphere (return to earth) rather substantial acceleration forces act on an astronaut.

The pilot's couch in the capsule of the vehicle must be positioned so that the acceleration forces act on the astronaut predominantly in the direction from the chest to the back (or from the back to the chest) or from left to right (or from right to left). In this case substantially greater acceleration forces can be withstood without harm to the organism. But given this direction of the acceleration forces we observe rather pronounced individual divergences in the ability to withstand the effect of acceleration forces. Therefore prior to a flight it is necessary to test the resistance of the astronauts repeatedly to the acceleration forces which are anticipated during the flight. Thus the tests on the centrifuge which produce acceleration forces that are close in duration, magnitude, and direction to those which are anticipated in an actual flight may, apparently, be regarded as one of the forms of astronaut training.

Is it possible to protect an individual against the harmful effects of increased gravitational forces and is it possible to raise his resistance to the effect of acceleration forces?

There are several methods to accomplish this. The primary method is training. The repeated action of acceleration forces produced on a centrifuge or during the flight of an aircraft promotes increased resistance to the effects of acceleration forces. Physical exercise involving the utilization of special sets of training exercises will also achieve this goal.

Moreover there are, if we can use this expression, technical means of increasing the ability of an individual to withstand the effect of acceleration forces. These means are based on the development of special facilities which aid the organism in combating the above-described disturbances, while at the same time improving the condition of the human being who finds himself under the action of increased gravitation. Such means include the so-called anti-acceleration suit. The lining of this suit includes inflatable rubber chambers. As acceleration forces make themselves felt compressed air is automatically fed into these chambers, thus producing increased pressure that is proportional to the increase in the acceleration forces (it is possible to do this as a result of special valves which permit the air to pass through). Pressing against the body, the suit prevents the shifting of the blood. As a result the ability to withstand acceleration forces is significantly raised (by 1.5-2 g).

Attempts are also being made to employ another principle. Apparently, the most effective is the method which had already been proposed by K.E. Tsiolkovskiy. The essence of this method was clearly demonstrated by the aforementioned in the following experiment. Dropping an egg into a glass filled with salt water (the density of the water was such that the egg remained in a suspended state), K.E. Tsiolkovskiy covered the glass with his hand and forcefully banged the glass against the table. The egg did not break. This means that the liquid protected the egg against the forces of shock acceleration.

The idea of protecting against the forces of acceleration by means of liquids of corresponding density was verified experimentally by a number of scientists, both domestic and foreign. All of these have pointed out the great future prospects of this method. It would seem that the problem was close to solution. However, there are still

a number of problems that have not been cleared up. For example, it must be borne in mind that the tissues of a human body are not identical in density and that the heavier ones will still shift despite the liquid, under the influence of acceleration forces and the shift will be even greater if the entire body is immersed in a liquid; therefore, this method does not offer any absolute protection, although there is no doubt that the resistance to acceleration forces is increased somewhat. In addition, immersion in liquid is associated with a number of inconveniences.

The most radical solution of the problem is the lowering of the acceleration-force magnitudes. The acceleration-force magnitudes must be such as to be completely withstood by the organism without any additional protective measures. We must believe that our remarkable engineers will also resolve this problem, as they resolved many other, no less complex, problems.

AN ISLAND IN THE UNIVERSE

Now let us turn to the scientific center where the future astronauts are being observed and readied. Before us we have a laboratory consisting of two adjacent rooms. One room looks like an ordinary laboratory room in which we see the familiar multiplicity of equipment. The other room is unusual and it is situated behind a thick door and a special small corridor. Let us look into this room.

Here it is clean, dry, and warm. A soft carpet deadens the sound of our steps. The walls have been painted in a silvery-bluish color. Daylight bulbs are glowing, but there are just a few of these, and they are not irritating to the eyes. The room is very small and filled with a variety of objects. It is extremely cramped in this room. One might think that these cramped quarters were deliberately set up in this manner. Standing in the center of such a unique windowless en-

closure it is possible to reach any shelf on the wall.

The soft fleecy armchair reminds one of the seats in passenger aircraft. It has a back which can be inclined to the rear. The footrest which extends when this is done converts the entire seat into a unique bed. It is quite simple to change the angle of the back and there is no need to get up in order to do this; it is enough to pull a lever.

The seat is surrounded by a variety of instruments and devices. Some of these have been polished to a mirror finish, and others are tinted in quiet hues.

The shelves carry boxes with specially prepared items, and there is water in an elastic plexiglas container. There is a sanitation device in the corner.

The air temperature is controlled by means of a special installation: as soon as the temperature rises above preset magnitudes, a cooling agent is emitted by a Freon refrigeration unit through tubes and the required temperature is restored. There are also a great many other devices. Each of these provides for the maintenance of the conditions that are required for the survival of a human being. Nothing has been forgotten, including the chemical cartridges - deodorizers - which absorb unpleasant odors.

Everything in this room has been adapted for the survival of a human being for many days and even weeks; he can work here, sleep here, and rest.

An isolated enclosure of this type, in which the normal composition of the air is maintained, where illumination, temperature, etc., are controlled, can also be employed to investigate the various aspects of providing for the normal functioning (life and activity) of an astronaut in flight (food, water, daily regime, etc.).

There is the expression "the natural cycle of matter in nature." Recall the pictures that you have seen in many of your textbooks: air, ground covered with trees and grass, water, animals. All of these were connected by double arrows pointing in opposite directions. This diagram presents a clear image of the basic processes which ensure life. Vegetation absorbs carbon dioxide and liberates oxygen. Animals, on the other hand, breathe the oxygen liberated by the vegetation and exhale carbon dioxide. Animals feed on vegetation which requires organic matter, and in the production of this organic matter, in turn, a great role is played by microfauna and fertilizer, i.e., the products of the vital activities of animals. Thus animal organisms make possible the existence of vegetation, and vice versa. We have a seemingly closed system which has everything that is required for life and its constant rejuvenation, for a complete cycle of matter.

Is it not then possible to employ the same principle to create all of the required conditions aboard a future space vehicle? After all, a space vehicle traveling away from the earth for many years cannot carry with it adequate reserves of water, food, oxygen, etc., for the entire length of the trip; therefore, a similar cycle of matter must be established during the flight. Here, as on a small island, all of the conditions required for the existence of life must be recreated.

As far back as 1915, K.E. Tsiolkovskiy first considered the problem of whether it was possible artificially to create such a cycle of matter, i.e., such a closed system. In 1916, his follower, the engineer F.A. Tsander, began to set up experiments directed at the solution of this problem.

Research chambers similar to the one about which we spoke just a moment ago in many respects may be regarded as such experimental

islands. And even though this experimental island is not yet in outer space but still on the ground, we can nevertheless still attempt to create a unique cycle of matter in order to provide all of the conditions required for normal vital activities.

The chamber has everything. It is possible to create the conditions required for artificial regeneration (renewal) of air. Research can be carried out on the various versions of regeneration installations based on chemical substances which, on decomposition, liberate oxygen and absorb carbon dioxide. It is possible to study vegetation exhibiting clear capacity to liberate oxygen and absorb carbon dioxide. In this case it is important to determine the specifics of growth and reproduction of such vegetation and to develop a nutritional medium which will provide for the best possible growth of such vegetation and to establish the level of illumination required for the existence of this vegetation, as well as many other things. Here in the water carried in tremendous plexiglas cuvettes fastened to the walls we find small single-cell algae. The cuvettes are bathed in the bright light of special daylight bulbs that are required for the process of photosynthesis. As a result of photosynthesis oxygen is liberated and carbon dioxide absorbed. It is pleasing to the eyes to see the thick bright-green mass of algae swimming in the layers of this water that is constantly being stirred.

We do not yet have the right to imagine how a future astronaut will pick ripe tomatoes or large red apples, but it may be that this dream of Tsiolkovskiy will someday be realized.

The process of air regeneration by means of vegetation is referred to as biological regeneration and the problems associated with this method have now become problems of great urgency in the field of space science. Even now the "heroine" of biological re-

generation - chlorella [algae] (single-cell green algae that is superficially similar to the algae covering the surfaces of ponds in the fall) - may apparently be used in space flights. This alga, occupying little space, liberates great quantities of oxygen. A total of only three kilograms of such vegetation is sufficient in order to provide a single human being with the oxygen required for breathing. At the same time, chlorella performs perfectly in its role as a "sanitation attendant" responsible for the removal of the carbon dioxide from the air, since the former represents danger to the human organism. Chlorella multiplies through cell division and grows extremely rapidly; this green mass of algae increases by factors ranging from 5 to 10 within a single day.

Another urgent problem is the supply of water for a space vehicle; it is true, of course, that many questions relating to this problem have already found positive solutions. The basic possibility of regenerating and restoring all of the moisture generated by a human being has already been demonstrated. The extraction of totally potable water from urine may also be regarded as having been solved from a practical standpoint. The urine is initially boiled and the formed vapor is trapped (distilled). The resultant condensate must be purified. The recently discovered so-called ion-exchange resins are used for this purpose. The water that has been filtered through such resins differs from ordinary water only in its somewhat higher content of acids. We will not dwell in any detail at this time on the other methods of regenerating water.

Scientists are seeking out all of the new possibilities which will enable us to provide food during a space flight. It is necessary that all of the substances required for this be products of the cycle of matter that has been organized under these conditions of a closed

space and that their wastes be employed for purposes of raising animals or vegetation. What offers the greatest promise in this regard?

It turns out that Chlorella is the most promising. It is nutritional and the small cells of this remarkable alga contain phytoalbumin, fats and vitamins. A good cook can prepare many tasty dishes from this substance. It is also heartening to know that this culture does not require great care; Chlorella need not be sown, watered, nor harvested.

However, Chlorella does not contain everything that is required by the human organism. In addition to the phytoalbumin and fats contained in these algae, substances which are contained only in products of animal origin are also required.

Let us take a closer look at the large emerald boxes containing the Chlorella. Here in addition to the green dots of these algae we also note representatives of zooplankton - small water animals that quickly develop together with Chlorella in the same medium as the latter. This substance, apparently, may also be included in the ration of a future astronaut, since it contains animal proteins. It remains only to make use of a net in order to harvest the Chlorella and the zooplankton.

And here we have another unique form of "game" - mollusks. In terms of their nutritional properties these animals are much like meat and, therefore, they are also included here. A paste of Chlorella, zooplankton, mollusks, and perhaps mushrooms will grace the table of future astronauts.

Scientists understand that for the prolonged functioning of this closed system and for the continuous restoration of the conditions required for life a variety of vegetation and many forms of animals are needed. Perhaps some of our conventional domesticated animals

may be completely suitable for the conditions prevailing in a space vehicle. It would be wonderful if a future astronaut, no matter how infrequently, could broil an actual earth chicken. By the way, it is completely possible that new forms of food which will be more tasty than such favored dishes as chicken and will require very much less work will be devised for the astronauts.

An astronaut will not experience any change between day and night during a flight. How will the human organism react to this situation? Despite the fact that such a phenomenon, at first glance, represents no danger, it will bring about the readjustment of a number of the physiological processes that are associated with the disruption of their natural rhythm and this may produce undesirable phenomena. How can these undesirable phenomena be avoided? Is the establishment of a rigid regime of human life the only condition required for the elimination of these afore-mentioned undesirable phenomena? How will a human being react to a change in this regime? Considering the various features involved, what is the best way of organizing the work day and the periods of rest for our space travelers? Here is yet another large group of questions which must be resolved through experimentation in the above-described unusual enclosure.

Let us assume that this enclosure now contains our future courageous investigator of distant planets. The heavy air-tight door has been sealed and before us we have a soundproof impermeable wall. The only thing that our astronaut is aware of outside of the chamber is the empty soundless cosmos.

However, such a comparison must seem funny to us. And as a matter of fact the adjacent room — "the empty soundless cosmos" — is now filled with more people than ever before. Here we find doctors, engineers, botanists, zoologists, and chemists. The researchers period-

ically check how the heart of the human being is functioning and how he is breathing. At definite periods of time an electrocardiogram and an electroencephalogram are prepared, and records are also made of other complex physiological functions. The many actions and individual movements of the astronaut are recorded. He is readying himself to eat, and then he eats and drinks. Engineers follow the readings on many instruments and devices and chemists keep a check on the gas composition of the air. The humidity and temperature of the air in the capsule (chamber) and other indicators are monitored constantly.

The attendant doctor constantly checks on the readings of instruments and although he cannot see the subject he knows his condition at any given minute or second. Night falls. The future astronaut spreads out on the couch and sleeps. Beyond the walls of his impermeable chamber a busy and intense life continues to protect his organism reliably against all possible unexpected events.

The above-described experimental chamber is a small cosmic island which must be the point of concentration of the basic contemporary achievements of space medicine, biology, chemistry and engineering. These achievements must be directed to provide the human being during a space flight with everything that is necessary for his existence and to investigate his reactions under these unusual conditions as well as to train the astronaut to exist within a chamber that is the prototype of the capsule of a space vehicle.

IN THE ISOLATION CHAMBER

As has already been stated, during the selection and training of a human being for space flight it is necessary to attempt to simulate on earth the factors and conditions with which this individual is liable to come into contact in the forthcoming flight and the effect of these conditions and factors must be tested on the organism of the

astronaut. This is a simple matter insofar as it pertains to such factors as acceleration, vibration, noise, etc.

But how are we to reproduce all of the factors that affect the psyche of an astronaut, i.e., the factors that will produce the complex nervous-emotional reactions which may arise during a space flight? How can we "test" most completely the psyche of a human being?

In order to answer these questions let us attempt to imagine the features involved in a flight into the cosmos from the psychological standpoint.

There is no doubt that these flights will exhibit a great many differences. They may involve either a single or double revolution around the earth, or it may be a case of a great many orbits. In all probability man will soon leave the near-by cosmos of our planet. This will, of course, immediately call for other time scales. After all, in order to fly to Mars, for example, to conduct an examination in the vicinity of this remarkable planet, and to return to earth thus answering many of the previously intriguing questions, a minimum of three years will be required.

An astronaut will, during a space flight, spend prolonged periods of time in an isolated capsule of small volume. This will, doubtlessly, be associated with great psychological difficulties. The human being involved will find himself under completely unusual conditions. He will be deprived of a significant number of accustomed stimuli that are characteristic of terrestrial conditions and, conversely, he will find himself affected by many factors with which he had not been familiar prior to this time.

Let us begin, for example, with the fact that he may possibly have to live under conditions involving an absence of weight. It is

extremely difficult to imagine the reaction to such a phenomenon if it lasts for days and weeks. Now, after the flights of Yu.A. Gagarin and G.S. Titov, it is clear that the effect of weightlessness produces no unfavorable symptoms even if it lasts for several days, but we still have no idea of the effect resulting from a stay in a state of weightlessness for a considerably longer period of time. Will not the prolonged absence of the accustomed nerve impulses usually transmitted to the central nervous system by the multiplicity of receptors (nerve formations receiving stimuli) produce a negative effect?

Further. The vestibular apparatus of the future astronaut — the organ of equilibrium — will also cease to perform its functions in a situation of weightlessness. A human being will be able to determine "where down is" and "where up is" only by means of vision, and should he but close his eyes, he will be unable to orient himself.

Unaccustomed stimuli will begin to affect the visual apparatus. Imagine that you can see only the very bright and the very dark — pronounced light contrasts — and that you are never able to detect any transitions.

It is difficult for you to imagine a situation such as this. After all, on earth we have grown accustomed to "soft" transitions between colors and shadings. Our eye is physiologically adapted to the sensation of shadings that are not too bright or pronounced. These light stimuli produce normal microchemical reactions in the receptor nerve cells of the retina of the eye and these reactions govern visual perception.

The bright rays of the sun cause pain, force one to squint and turn away, and if one were not to squint or turn away, the cornea of the eye would be burned. Less bright but nevertheless intense light disturbances also have a negative effect on our vision and irritate the

retina of the eye and tire a man's vision. Pronounced contrasts, i.e., transitions from bright to dark, and vice versa, also have a negative effect. These require such rapid adaptation of the mechanisms of vision that even pronounced pain may result. Because of these sharp contrasts depth perception may be reduced and the stars will appear like bright spots on a dark surface to our eyes.

But that is not yet all. People have become accustomed to a frequent change in visual impressions, i.e., the various items and phenomena before our eyes are almost constantly changing. In this case, if one is called upon to spend a long period of time in the same surroundings he is likely to experience the wearying sensation of loneliness and irritation. Everyone knows how important it is, in this situation, to get away from these conditions for even a short period of time and to vary the surroundings.

The astronaut, however, will be deprived of such an opportunity. He will always be confronted with the identical items in the capsule, and if he looks out through the observation window he will be confronted by a black haze in which he can see nothing but bright unblinking stars. Nothing in the space surrounding the astronaut will change: everything will seem to have been frozen in place and seemingly drawn on the material screening the window.

No matter how quiet it seems to us on earth, we live in a world of constant and various sounds. If we listen carefully we will, at once, hear many rustling sounds as well as other soft and pronounced noises. And there are many noises which cannot be detected by us because of their limited magnitudes, even though these affect us, through our brain, and excite groups of nerve cells. In this sense of the word, we know no silence under the conditions prevailing on earth.

It has been demonstrated by science that this definite (although

undetected) background of noise [sound] is necessary for the functioning of the human brain. This background of sound, acting upon us without being detected, nevertheless participates in the establishment of phenomena that are extremely important for the functioning of the brain, and we have reference here to the fact that it is precisely this background of sound that maintains the tonus of the brain processes. Therefore the absence of sound on earth cannot help but be felt by a human being.

In connection with a space flight, evidently, the disappearance of many other usual stimuli acting on a human being under terrestrial conditions is to be expected. We know that people react negatively to the absence of disturbances from the outside world. This was clearly demonstrated by many researchers.

Imagine, for example, a human being dressed in a special suit and sitting in a couch that has been installed in a small cramped chamber. The suit precludes the possibility of the body of this man being disturbed by external stimuli (greater air humidity, change in temperature), and in addition the suit prevents this individual from moving about, nor does the suit permit any of the sounds and light in the chamber to penetrate. This man spends a day, two days, and longer in a half lying position. He sleeps almost all of the time. After all, his cerebral cortex, receiving an extremely limited number of signals from without, falls into an inhibitory state.

The same data were obtained abroad in tests in which people were immersed in thirty-five-degree water in which they experienced neither heat nor cold. The mask which they wore was painted black and prevented the penetration of any visual stimuli, with the only tactile stimuli those that were caused by the pressure of the mask itself. The conditions of these experiments were established so that

the individuals being tested were not subjected to any visual or aural stimuli. Such virtually complete isolation of a human being from any external intelligence had a serious effect on his psyche. The people were transformed into beings that seemed to be in a long-lasting sleep which, however, was disrupted as they returned to normal surroundings.

A number of authors have stated that an individual is incapable of withstanding well the absence of external stimuli. People who have been placed in a specially equipped box in which conditions of maximum insulation against external stimuli have been created began to change the positions of their bodies frequently, they started to execute intense movements, and they even pounded against the walls of the box. In many cases, after 24 hours, all concept of time was lost and hallucinations appeared; the scientists were forced to cut the experiment short.

These are the resultant facts. It is true that these facts relate only indirectly to the astronauts, since there will be no complete absence of sensory stimuli in space flight. However, it must be borne in mind that the total number of stimuli in cosmic flight will be markedly decreased. It is for this reason that all of these data are of great interest. Much of the material relating to the nervous-emotional system is extremely complex and not yet subjected to thorough study insofar as this pertains to the conditions prevailing during extended existence aboard a space vehicle. This fact makes itself particularly strongly felt in the case in which only a single individual is sent on a flight, but it pertains even to the case in which the crew of a space vehicle consists of several people and there will be many questions that remain unclear and unresolved.

Let us assume that the astronaut who has the courage to under-

take a trip into outer space is to remain isolated for a long period of time. In all probability, or so it will seem to many, this would not be so terrible. We can recall a number of explorers who found themselves in situations similar to that of Robinson Crusoe who were either forced or desired of their own free will to bear the burden of solitude without losing their spirit. However, there are many examples of the reverse. Consequently, everything is not quite that simple. A human being is a social being. During the course of many thousands of years contact with people has become an absolute necessity for the human being. Therefore, it becomes difficult for a human being to spend weeks without hearing a spoken word and without having any possibility to speak to other people. The astronaut finds himself surrounded only by the boring walls and instruments which he sees day in and day out, each minute and every hour. Moreover, he cannot open the door and leave his enclosure, even for a short time. There is no change in the bright impressions and there is no intense struggle for existence. There is nothing that relieves the sensation of having been torn away from the world, nor is there any reduction in the longing produced by his isolation. An individual deprived of all opportunity to socialize with and to look at people finds it extremely difficult to survive under conditions of prolonged solitude; irritability sets in and some people begin to talk to themselves, they become unnaturally excited or, conversely, lethargic.

This separation from the earth will also make itself felt. The astronaut will find himself in a tense state of alarm, and this is quite natural under the unusual conditions which prevail during space travel.

In tentative terms, let us imagine the psychological background which in many ways determines the capability of the individual to

carry out the multiplicity of complex assignments which confront the crew of a space vehicle.

If to the nervous-emotional features of a space flight we add those purely physical difficulties which an astronaut will experience and about which we have already spoken, then it is a rather complex set of circumstances which await the astronaut during the flight.

Is a human being capable of withstanding a prolonged flight into outer space? There is no doubt that this question must be answered affirmatively, and for the following reason.

Many of the possible unfavorable sensations experienced by the human being will be eliminated. Engineering comes to the assistance of the individual in combating a number of these difficulties. Secondly, the human organism can adapt to many unusual conditions and the possibility of such adaptation is extraordinarily far-reaching.

Engineering and technology can be employed to eliminate, if necessary, the phenomenon of weightlessness by the creation of artificial gravity. Light filters can be employed to reduce the unaccustomed brightness of solar illumination. Radio and television can fill the capsule with the sounds of human speech and music, thus somehow bringing the dear and beautiful earth closer, i.e., it will be possible to sense the living breath of the earth. There is no doubt that a vehicle will be designed to carry one, two or more astronauts on a prolonged space flight. In this case, people will be able to associate with one another.

As we have already stated, in order to control the dangers and difficulties that are likely to be encountered during a flight, the capacity of a human being to adapt to the wide variety of conditions prevailing in the external medium is a matter of extreme importance. In this connection we take note, in particular, of the amazing adapt-

ability of the human nervous system. The nerve cells of the cerebral cortex, in addition to the many other systems of the organism, have protective properties at their disposal to protect against serious consequences.

If, for example, strong stimuli exceeding the physiological limits of nerve-cell viability (and this may include such physical factors as noise, light, etc., or emotionally difficult experiences, fear) act on the cerebral cortex, the nerve cells enter into a state of so-called protective inhibition in which case the stimuli cease to excite the nerve cells. The resulting inhibition thus protects the cells against destruction.

The human being can also adapt on a wide scale to less significant stimuli. We have seen this in ourselves in a thousand examples in which a person simply and easily adapts to new and sometimes even difficult conditions.

The nervous system in this sense of the word possesses a multiplicity of reserve potentials. Such potentials must be brought out into the open, just as was done with the potentials of the cardiovascular and similar systems. Only individuals with the best possible of nervous systems should be selected for space flights.

How can people be trained for space flights under terrestrial conditions?

It is impossible to acquaint a human being with certain space-flight factors on the ground. It is impossible, for example, to train individuals to coordinate their movements when body weight has been reduced to zero; this is impossible because we are unable to recreate the state of weightlessness under terrestrial conditions. The vestibular apparatus of a human being cannot be prepared especially for new stimuli. It is impossible to test the capability of a future as-

tronaut to withstand the emotional stresses that are associated with the risk of a space flight, etc.

As a matter of fact, there is a solution even to this problem; the state of weightlessness can be tested for periods of 30 to 40 seconds by flying in special aircraft. And later on, perhaps, in preparation for prolonged space flights the astronauts will be called upon to execute short-duration orbital flights around the earth. This, in all probability, is a matter for the not-too-distant future.

It is possible, under terrestrial conditions, to study the effect of other flight factors as well as to do research on the features of the human nervous-emotional sphere. It is possible, for example, to make an attempt to learn how a future astronaut, isolated from his conventional world, will feel and how he will take to the artificially created tightness of his capsule, as well as to study whether or not his psychological functions and the nature of his motor responses will change; will he be capable of making prompt and valid decisions under various emergency conditions, etc. After all, many western scientists maintain that the sensation of total isolation stays with an individual for a long time, and actually increases with time to have a pronounced effect on the human psyche. Is this the actual case?

We are, consequently, faced with an unusual task — to investigate the features of the nervous-emotional sphere of a human being during his isolated stay in a special enclosure. The isolation chamber which should be examined is similar to the experimental chamber described in the previous section. But other instruments have been set up here. And this is understandable; after all, it is our task here to resolve problems that are associated with the psychological reactions of a human being.

It may be that we should investigate the problems of providing

for the life of a human being and his psychological reactions simultaneously, i.e., in a single chamber. In this way we will obtain a more complete picture, one which will correspond more fully to the conditions that await an astronaut during a flight.

Thus let the reader imagine all of the things about which we are about to speak as happening under conditions in which air is being regenerated, the required temperature is maintained, the future astronaut consumes specially prepared food, and the psyche of the individual is also being subjected to simultaneous study.

Let us enter this laboratory. The heavy air-tight door to the chamber is closed. The human being has been inside, under conditions of complete isolation, for a long time. He is completely deprived of any external intelligence, i.e., he has not received a single signal.

As a matter of fact, the future astronaut is transmitting information about himself, about temperature, on humidity, and on other indicators of the air in the chamber. By means of flashing lights he signals that he has awakened, that he feels well, that he is prepared to record physiological functions, that he is starting to eat, etc. But he receives no replies nor does he even know whether anyone has received his signals.

As far as he is concerned he is alone, completely alone. Our subject proves this to himself each and every day; everything that surrounds him points up his close relationship with the outside world.

But such a relationship does exist and each step of this individual is carefully observed by the experimenter who can hear and see everything that is happening within the chamber; however, the subject can neither hear nor see, i.e., this communication is strictly one sided.

The doctor in charge opens the screens covering two television sets. Now we have the astronaut before us. One television set shows the astronaut from the side, the other set shows him full face. There is a serious expression on his face. He has pulled up the sleeve of his shirt and he is looking at his wristwatch. He waits until the hands of the wristwatch have stopped on the numeral 6. Expertly he fastens the electrodes that are used for the recording of the electrocardiogram and he checks to see that they are properly connected.

Each action of this individual has been predetermined by a precise schedule. He had studied the form and sequence of all the operations he is to carry out even prior to entering the chamber. His innate feeling of discipline, instilled through his training as a pilot, compels him to be precise in all of his actions. And this despite the fact that he is completely unaware of the systematic monitoring of his behavior.

The chamber is equipped with a variety of instruments and equipment. Placed on shelves and suspended from the wall, some glisten with the soft colors of their frames and because of the ground glass with which these instruments are equipped. Other instruments and pieces of equipment are fastened to the floor. The round heads of the receiving equipment are raised and lowered above the couch, like a flower, by means of thin bent legs. These instruments are employed to confront the subject with a variety of psychological tests and to record the resultant data and the subject's responses.

Here is an installation which includes a lamp. This lamp is capable of flashing light at various frequencies. Here is a sound generator, a device which resembles a headset and is employed to produce sound signals of varying duration and intensity. Alongside are instruments which record the response reactions of the individual.

This equipment can be used to test the nature of the visual and aural reactions of the individual.

The electrodes that are fastened to the head of the subject make it possible to detect the biological currents of the astronaut's brain during the period that he is affected by these stimuli, as well as prior to and after their action.

Thus the experimenters have at their disposal a great variety of data. In their entirety these data make it possible to arrive at conclusions regarding the subject's perception, the degree to which he becomes tired, etc.

Here the astronaut, having looked at his watch once again, turns his head and looks at the columns and groups of flashing red and black numerals before him. We can see on the television set that he has begun to speak and we can actually hear the click which turns on the equipment and the clear words: "Am proceeding to the execution of assignment No. 12."

A human being's life, his behavior and his psyche are extremely complex and varied. How are we to determine the features of even individual aspects of his psychological activity? How, for example, are we to determine the quality of his attention, the degree of concentration and his ability to function under unusual conditions? We will be aided in answering these questions by using the special methodological procedures that are directed at the determination of the features of the human nervous-emotional sphere. Such methodological procedures, as a rule, are used in conjunction with a complex of physiological investigations. This creates additional possibilities for a thorough study of the psychological-physiological features of the individual involved.

Let us assume that the assignment is to read tables of numbers.

The instruments record exactly the time at which the individual stages of the assignment have been completed. A tape recorder carries the vocal reactions of the subject and these may indicate his emotional state during the process of carrying out the assignment. Simultaneously, an electroencephalogram (the biological currents of the brain) of the human being is taken. Later on all of this information is compared and analyzed. The differences in the execution of the assignment during the first, the second, and subsequent days of his stay in the chamber are determined.

Let us present yet another example; the astronaut keeps his eye on the flashing numbers which are out of sequence and he calls each of them out in proper sequence; here the red numerals indicate ascending order and the black numerals indicate descending order. At first glance this seems simple. But there is a great variety of individual differences (within the limits of normal reactions). Some people do this slowly, others hastily; some people make no mistakes at all, while there are people who make many mistakes.

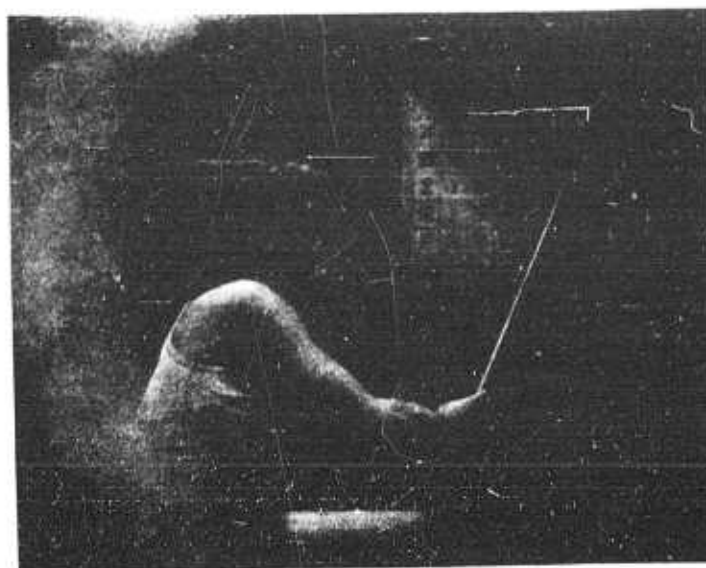
On the television screen we can see how the future astronaut, despite the conditions of isolation, quickly and clearly finds the required numbers in sequence and we can hear his voice: "Four, red; and twenty-one, black; five, red," etc. These two rows of numerals converge in the middle and the problem becomes more difficult. It is hard not to make a mistake when the basic characteristics are close in value and when these numbers have been jumping in front of your eyes for a long time.

But the astronaut is well able to cope with these difficulties. There is only a slight delay in the speed of his responses, and his face shows greater concentration (this can be clearly seen on the television screen).

On another occasion, as the subject approaches a more difficult section of the problem, he is interfered with deliberately; a long series of various sounds is injected. Try not to lose the count under these circumstances.

Things are made even more difficult when sounds are made to emanate from a loudspeaker that relate directly to the assignment being carried out. For example, the subject is solving a similar assignment out loud, and his ears are bombarded with numbers that are similar to those with which he is operating. An inner discipline and the ability not to be distracted is required in order not to lose track.

Having received high grades in these various psychological tests, the future astronaut shows virtually no reduction in the quality of his execution of the assignment during the entire period of his stay in the isolation chamber. He is also not terrified by the interference with his solution of the problem.



G.S. Titov in the isolation chamber.

Let us continue to look at the screen of the television set. It would seem as if the astronaut would now have an opportunity to rest.

But no, attentive to his instructions, exactly at the prescribed time he begins to attach another apparatus to himself. This time his right hand is connected to a large complex of instruments. Now we have before us a series of simple and complicated movements on the part of the subject.

Moving away from the television screen we observe for a long period of time the slowly moving paper tape showing the recordings of various characteristics of the movements being executed by the future astronaut. Here in odd lines we can see clearly the individual components of the movements, the amplitude, directivity, intensity, and rate. Simultaneously there are recordings of the various physiological functions (pulse, respiration, pressure in the blood vessels, etc.).

During one of his days in the isolation chamber our future astronaut will be called upon to resolve a problem involving the elimination of an "emergency situation." He will not be aware of the fact that this situation has been thought up to test his nervous-emotional resistance, since the situation will, to his eyes, appear to be one of actual urgency.

Imagine the following: unexpectedly a red light flashes on a table in front of the astronaut, and this red light signals the occurrence of a great and threatening "danger" such as, for example, a pronounced drop in the air pressure inside the capsule. Under such conditions the astronaut must be able to take stock of his situation, determine the possible factors responsible for the "emergency," and to summon all of his knowledge in order to eliminate the "danger." And all of this must be done quickly, under circumstances in

which each second counts. It would be quite easy to become mixed up under these circumstances. Thus the features of this individual's nervous-emotional sphere are brought to light most vividly.

The facial expressions show extreme concentration, his gaze is rigidly fixed as it scans the instrument panel, there is not the slightest hint of confusion, and his movements are precise. And only when everything has been "corrected" do we hear the relieved sigh of the man who has just gone through some very difficult minutes; this is the only sign which indicates the stresses which he has just experienced. This is our future astronaut.

Various psychological procedures make it possible to determine how perception, attention, memory, thought, emotional resistance, and functional capacity of the future astronauts will change when they are exposed to a prolonged stay under conditions of total isolation. The special experiments set up by Soviet scientists have enabled us to determine that people who find themselves under these conditions may react in various ways to these conditions. Some people preserve their ability to function, carrying out all of their assignments, maintaining their daily regime, and never lose their time orientation. In other words, their behavior differs little from their behavior under conventional conditions. They exhibit virtually no change in mood and they remain identically alert throughout the entire experiment. These are people with a stable nervous system.

Other individuals, conversely, show increased irritability phenomena. They begin to show confusion in their assignments and they become giddy and alternately apathetic.

It is for this reason that it is so extremely important to select astronauts under the above-described conditions. After all, only in this manner can scientists determine the features of the nervous-

emotional sphere of each candidate and the stability of this sphere under the conditions prevailing during the experiment.

Now our future astronaut leaves the chamber upon completion of the experiment. We have, before us, a rather short and smiling individual. He jokes happily about his extended incarceration and looks about him happily at the people gathered close about him. No matter what you say, it is pleasing to find yourself in human company once again.

HYPOXIA

Let us describe yet another laboratory with which, evidently, we will have to familiarize the people who are striving to become astronauts. We have reference here to the low-pressure laboratory — the so-called barolaboratory.

Imagine a metallic rectangular (or cylindrical) chamber that is closed by means of an air-tight door. The inside volume of this chamber is not great — slightly less than 10 cubic meters. As a matter of fact, there are substantially larger pressure chambers. The operational principle of such a chamber is quite simple. Two tubes are connected to the chamber; one of the tubes is attached to a vacuum pump and the other connects the inside volume of the pressure chamber to the atmosphere of the room or outside air.

Let us close the atmosphere tube. Let us start the pump and evacuate the air. Rarefaction will be produced inside the chamber and the air pressure will begin to drop. Now let us close the vacuum tube and open the atmosphere tube — the air will stream inside and the pressure will level off to that of the outside air.

If a man were to be placed inside the pressure chamber he can thus be made to "experience" various altitudes without leaving his place; the pressure chamber makes it possible to create the basic

conditions which are inherent in various altitudes, i.e., a given degree of air rarefaction.

Let us assume that you want to climb to an altitude of 5500 m. Enter the pressure chamber and sit down on the chair and wait. A mechanic will turn on the pump which will evacuate the air from the chamber, thus creating rarefaction corresponding to an altitude of 5500 m. Simultaneously, the air temperature can be reduced and in order to do this a special refrigeration installation is provided. Thus it is possible "to raise" and "lower" people to various altitudes.

Contemporary pressure chambers intended for biological purposes are complex technical installations in which it is possible to create various temperatures (the range is from -60° to $+70^{\circ}\text{C}$), and rarefaction corresponding to altitudes of 20 to 30 km. Pressure chambers are equipped with complex equipment which records the physiological functions and instruments which can monitor the "ascent" and "descent" regimes, etc.

Research in pressure chambers has been employed for a long time for medical examinations of pilots. In this connection there arises the natural question as to the reasons for such investigations when contemporary aviation has at its disposal aircraft equipped with pressurized cabins and oxygen-breathing equipment, thus making it possible for a pilot to function under conditions of rather high barometric pressure without experiencing a shortage of oxygen during the flight.

The required level of barometric pressure and the corresponding content of oxygen will doubtlessly also be provided for in the capsules of space vehicles; however, astronauts like pilots will, apparently, have to undergo tests in pressure chambers.

The situation involves the fact that research under conditions

of a rarefied atmosphere in which an individual experiences a shortage of oxygen serves as an excellent test by means of which it is possible to reveal any latent defects in the cardiovascular and nervous systems, as well as to determine the specific features of the functional state of the organism. It is for this reason that ever-increasing importance is ascribed to the so-called hypoxia tests at the present time.

Let us take a look through the observation window of the pressure chamber in which our pilot is enclosed. The vacuum pump is working and the pressure in the chamber continues to drop. This is the "ascent" stage.

The "altitude is 4000 m" and this means that the barometric pressure in the pressure chamber has dropped to 462 mm Hg (this is the pressure magnitude at an altitude of 4000 m). We note the fact that the pilot is expending somewhat more time than usual to solve a number of rather simple arithmetic problems. His handwriting has changed, i.e., it is no longer as even and as clear as before.

The "altitude is 5000 m" and the subject's face has grown redder, his pulse has climbed to 95 beats per minute, and his respiration rate has also risen. However, the pilot's mood is excellent, he is laughing, he answers jokingly to all questions, indicating that everything is fine; he is experiencing only slight dizziness. The "ascent" is brought to a stop at an "altitude" of 5000 m. After 20 minutes the subject's happiness is replaced by apathy, sluggishness, and his movements become slow and labored. His pulse rate increases even further, breathing becomes even more difficult, and his lips turn ever bluer. It is imperative to begin the "descent," since otherwise the subject may faint.

Here is yet another example. The "ascent" conditions are the

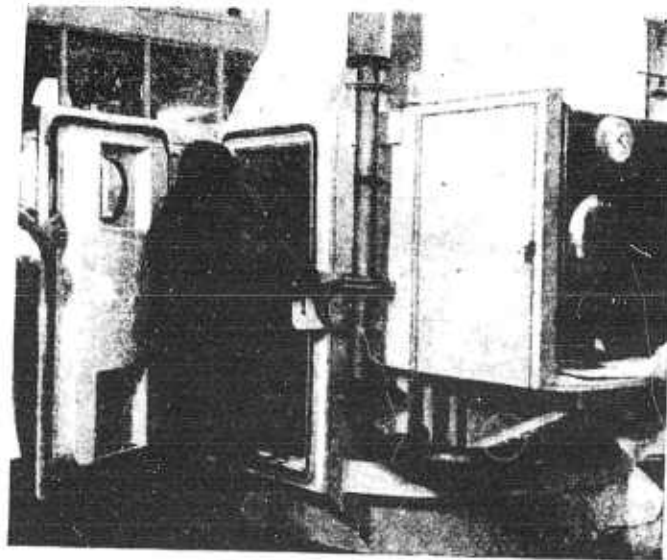
same, but we have another pilot. He is able to withstand greater air rarefaction substantially better. He exhibits virtually no disruptions of his normal functional activity at altitudes of 5000 m, nor at an altitude of 5500 m. He sits quietly in the pressure chamber. After the passage of 30 and 40 minutes, and even after 1 hour, there is virtually no change in his condition. He carries out all assignments satisfactorily, there is some increase in the frequency of his cardiac contractions and in the respiratory rate, but by no means is this increase as pronounced as in the case described above.

How can this be explained? It turns out that the second pilot has already experienced the conditions of oxygen starvation several times and because of his individual characteristics he is better able to resist reduced barometric pressure and a shortage of oxygen.

Individuals who exhibit low resistance to a shortage of oxygen experience dizziness, weakness, disruption of coordinated movement, and increase in the pulse rate to 120 and more beats per minute, lips turning blue, etc., i.e., a condition which calls for the rapid descent to safer altitudes, during the first 10 minutes at an altitude of 5000 m when the partial oxygen pressure in the lungs is equal to 45-50 mm Hg (under normal conditions this partial pressure is equal to approximately 100 mm).

In contrast, there are data indicating extraordinarily good resistance to altitude. For example, on 21 November 1935 V.K. Kokkinaki established a high-altitude flight record by climbing to an altitude of 14,575 m. Approximate calculations showed that the oxygen pressure in his lungs was equal to 22 mm Hg at this altitude.

How do the basic physiological functions of a human being change with a drop in barometric pressure and with the resultant shortage of oxygen in the air being inhaled? Why is the investigation in the



Outside view of the pressure chamber.

pressure chamber such a valuable procedure for diagnosing inadequacies of the cardiovascular system, i.e., inadequacies not revealed by other methods, and why is it such a valued method for the determination of the functional features of the organism?

The constant and typical respiratory reaction to a lack of oxygen is an intensification of lung ventilation: a man begins to breathe more rapidly and deeper. As a result, a substantially greater quantity of air passes through the lungs per unit time and as a result the blood is kept saturated with oxygen to a sufficient degree. For example, on the ground approximately 8 liters of air pass through the lungs per minute; at an altitude of 5000 m, this figure is approximately 11.5 liters. Thus we cannot help but arrive at the conclusion that in the case of a lack of oxygen in the air it is better for a human being if his lung ventilation is greater. However, this does not happen to be the case.

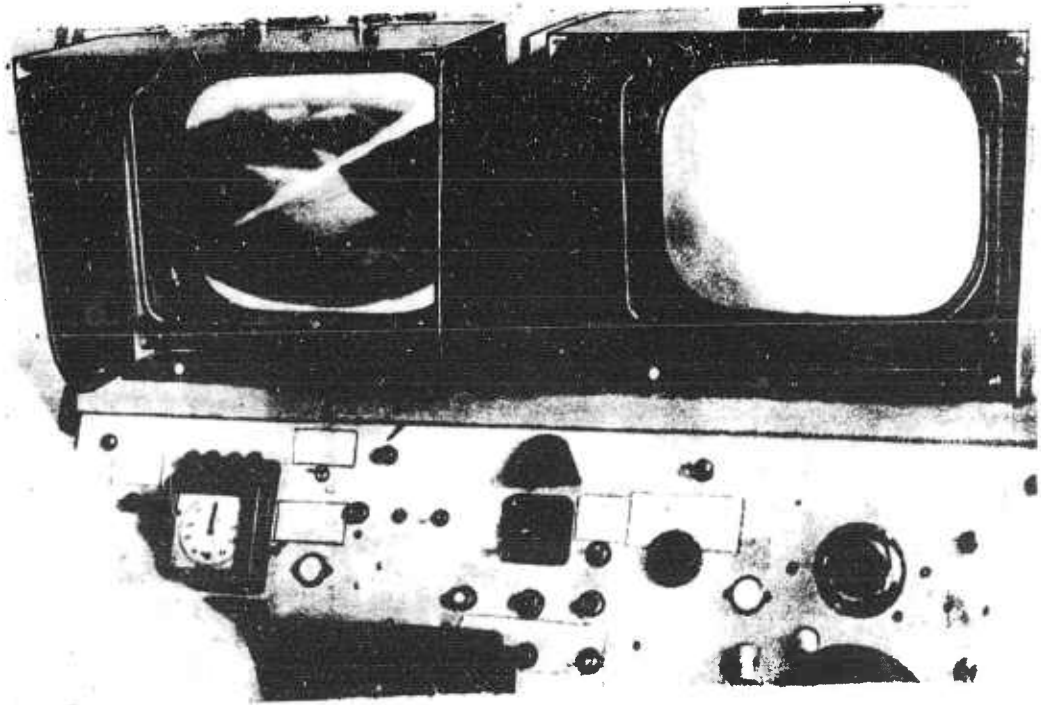
Try to breathe in and out as quickly as possible. After a certain

period of time you will become dizzy, lose equilibrium, and you will be forced to stop respiration. In certain cases, the individual doing this exercise may actually faint. This is a result of an artificial increase in lung ventilation and it is also a result of the concurrent reduction in the quantity of carbon dioxide (CO_2) in the lungs.

Under ordinary conditions there is a definite quantity of carbon dioxide in the lungs at all times, and this carbon dioxide is brought in by the blood. If there is a pronounced increase in the frequency and depth of respiration, the CO_2 is flushed out of the lungs in greater quantities and its concentration in the blood is reduced. The carbon dioxide serves as a stimulus of the respiratory center in the brain, i.e., the nerve center which transmits periodic pulses to the respiratory muscles engaged in the act of inhalation. If as a result of increased ventilation the CO_2 concentration in the blood is reduced, the respiratory center is not stimulated and transmits no pulses, i.e., it does not give the "signal" for inhalation. By strength of will you can, for some period of time, force breathing, but in this case the normal nervous impulsion from the respiratory center is markedly disrupted and you will lose consciousness. In this case, naturally, respiration is stopped for a certain period of time and this results in an increase in the quantity of CO_2 in the blood and the normal respiratory cycle is again restored.

Now imagine that there is little oxygen in the air. As a result of hyperventilation the concentration of CO_2 in the blood has also been reduced and this resulted in a prolonged retardation of respiration; however, this is bad under the given circumstances, since it results in the blood being even less saturated with oxygen than before.

We have characterized the respiratory reactions in the case of hypoxia (shortage of oxygen) in detail on purpose; however, we have



Everything is in good order in the pressure chamber.

by no means presented a complete physiological analysis of the phenomena that were observed and we have particular reference to the fact that we did not dwell in any detail on the complex neuroreflex processes nor on the role that oxygen plays in the regulation of breathing, etc.

Thus the reader can see the extent to which the processes of regulating the physiological functions in an organism are complex and precise. If an individual is placed in a condition of hypoxia, the resulting changes in the physiological processes make it possible to render a judgment regarding the reserve potentials of the organism. It is for this reason that the "ascents" in the pressure chamber must, obviously, be employed in examining astronauts.

The reactions on the part of the cardiovascular system are of particular significance, since these reactions are easily detected by

simple research methods and it may turn out that in addition to the changes in external respiration these reactions serve as excellent indicators of the state of the organism.



Test subjects at an "altitude" of 5000 m.

As has already been pointed out as the gain in altitude proceeds, i.e., with an increase in the phenomenon of oxygen starvation, there is observed a speeding up of the pulse rate which indicates the increase in the number of cardiac contractions. There is also an increase in the shock volume of the heart, i.e., the quantity of blood expelled by the heart during a single contraction. As a result, a greater quantity of blood will flow through the lungs and tissues per unit time and this will enhance the supply of the required quantity of oxygen to the tissues.

All of these reactions serve to offset the shortage of oxygen in the air being breathed in (atmospheric air) to altitudes of 3 to 4 km. With a continued drop in barometric pressure and with the related drop in the quantity of oxygen, the reserve potentials of the organism will prove to be inadequate and we observe symptoms of increasing oxygen starvation.

The nerve cells of the cerebral cortex are the first to react to a reduction in oxygen. In this case, even a slight inadequacy of oxygen has a stimulating effect on these cells, while a substantial inadequacy serves to depress the functions of the cortical cells. The stimulation phase generally appears at an altitude of about 3000 m and is characterized by a jubilant mood, sharpness of attention, and increased interest in surroundings. The second phase — the depression phase — begins generally at an altitude of about 4000-4500 m. During this phase the ability to work is reduced, and the capacity to evaluate a situation correctly and critically is reduced as is the ability to allocate and switch attention; in addition, the ability to observe is reduced, as is initiative, and also, and this is extremely important, the individual generally is incapable of correctly evaluating his condition, his actions, i.e., he is not self-critical. He is under the impression that everything is proceeding well, i.e., the state of so-called euphoria sets in (a feeling of slight excitation). This period is marked by false impressions, thoughtless persistence, unawareness of danger, etc. It is therefore completely improper to rely on the personal evaluations of the astronaut regarding his ability to withstand oxygen starvation. Subsequently this state is replaced by an impairment of the over-all well-being, by apathy, by general weakness, drowsiness, and indifference to external stimuli.

The manifestations of hypoxia are subject to substantial indi-

vidual variations. People who exhibit high resistance to hypoxia, i.e., people who have been trained or who exhibit high functional reserves, exhibit these manifestations in substantially less clear form and these manifestations make their appearance at a higher altitude than in the case of individuals with lower reserve potentials of the organism. Therefore researchers devote such great attention to the hypoxia tests.

It is of interest to note that in all manifestations of an oxygen deficiency the unfavorable phenomena can, through force of will, be suppressed to a significant degree; in any event, it is possible to continue to behave as usual and to carry out the assigned work. Therefore the tests in a pressure chamber may, to some extent, reveal volitional properties of an individual.

A two-seater aircraft quickly gains altitude. In the forward cockpit sits a pilot who is controlling the aircraft, while a doctor is seated in the rear cockpit. The doctor is to carry out certain tests during the course of the flight. The doctor is wearing an oxygen mask, but the pilot does not use any such device.

The aircraft continues to climb to a higher altitude. The altimeter now shows an altitude of 5600 m above sea level. The doctor makes notes of his observations. But suddenly he notes that the aircraft has undergone a pronounced change in flight. The ground is approaching with threatening speed, the aircraft is dropping quickly, virtually falling. Looking into the forward cockpit the doctor is horrified to see that the body of the pilot is freely suspended from the restraining straps, the pilot's head is drooping, and the control stick is, apparently, grasped in a cramped grip. The altimeter readings are changing with catastrophic speed - 4000, 3500, 3000 m.

But now the pilot begins to lift his head, he looks around, and he smoothly pulls the aircraft up into horizontal flight and quietly,

with his usual skill, takes the ship in for a landing. After the landing the doctor asks the pilot what had happened during the flight and how the pilot feels at the moment. The pilot looks at the doctor strangely and announces that the flight could not have been better and that nothing had happened to him during the flight; at the moment he feels fine. Even after the pilot was shown the record of the irregular flight, and this record clearly showed the entire flight profile, he doubted for a long time that this had actually taken place, and this was indicated by the fact that the pilot spread his hands in bewilderment.

This fact pertains to the past, i.e., to the period in which high-altitude flights were first attempted, and to the period in which oxygen devices were first being introduced. However, even now we can see cases of sudden fainting during "ascents" in a pressure chamber.

With a rapid gain in altitude, when oxygen starvation develops in short intervals of time, all of the compensatory mechanisms cannot come into play quickly enough and the sequence of the appearance of various symptoms is disrupted. In this connection, a state of unconsciousness may steal up on an individual without giving any prior indication. There are cases, rather frequent, in which against a background of complete wellbeing and satisfactory state of health in a pressure chamber, the subject suddenly experiences cramps and loses consciousness. This is the most insidious effect of oxygen starvation. Usually everything ends well, if the barometric pressure is raised quickly.

It is characteristic that the subject remembers absolutely nothing about what happened to him; he is amazed and asks why the test had been curtailed and it is extremely difficult to convince him that he had lost consciousness.

We have by no means described all of the phenomena which are observed with increasing hypoxia. In particular, there are pronounced changes in visual functions: the time required to distinguish items is prolonged and visual acuity is reduced. As low as 3000 m the subject's ability to sense color begins to show signs of reducing, while at an altitude of 5000 m it becomes difficult for him to distinguish colors. The ability to perceive the color "red" is preserved for the longest period of time. If the subject were to put on an oxygen mask at this altitude, he would find that all of the colors that had, prior to this time, been pale and difficult to distinguish would now flare up in their bright hues.

There is no need to dwell in detail on the changes taking place in other organs and systems of the human organism under the influence of oxygen starvation. In all probability, it is quite clear that a doctor studying the reactions of a healthy human organism subjected to hypoxia can arrive at important conclusions.

There arises the natural question as to whether or not and how it is possible to protect a human being against oxygen starvation.

It would be simplest of all to breathe pure oxygen. Indeed, this is what is actually done. Special oxygen devices have been designed, and these can be used by man in order to add the required quantity of oxygen to the air being breathed, and even fully to replace air with pure oxygen.

However, at an altitude of about 13 km a human being dies because of a deficiency of oxygen even in the case in which he has access to pure oxygen. It turns out that in order for the blood to be saturated to a sufficient extent with the required quantity of oxygen, the oxygen in the lungs must be under a certain pressure, and the barometric pressure at an altitude of 13 km (and consequently, the pressure

of the oxygen in the lungs) is so low that the blood is not sufficiently saturated with oxygen.

Thus in order to make it possible for a human being to breathe, the quantity of oxygen and the barometric pressure must both be sufficiently high. It is for this reason that in aircraft flights, and this applies particularly to flights of space vehicles, the cabins must be pressurized and the appropriate barometric pressure must be maintained. If, however, the pressurization of the cabin is lost or, for example, if the astronaut must leave the capsule then it is necessary to put on a spacesuit. The air beneath the helmet of the spacesuit will be saturated with oxygen, and it is possible to maintain the required air pressure between the layers of this special form of clothing. Thus, the astronaut will find himself surrounded by a virtual pressurized cabin.

... Our imaginary tour through this unusual clinic has come to its end. There is no reason to doubt that it is precisely in such a medical institution that the examination and selection of the participants of future space flights takes place.

ATHLETIC TRAINING

Everyone knows of the great importance of athletics for the health of a human being and everyone is also aware of the favorable influence exerted by participation in physical-culture exercises on the nervous system, the heart, the muscles, etc.

The special physical exercises used in therapeutic physical culture aid in warding off many, even serious diseases, the after-effects of burns, wounds, and poisoning. On-the-job gymnastics aid in the better fulfillment of the plan, etc. In other words, an "athlete" generally makes us think of a strong, happy, and confident individual.

But in addition to the health, social, and every-day aspects of physical exercises, these can also play an important role in the execution of purely professional activities. Sailors must be good swimmers, infantrymen must be good shots, etc.

A professional astronaut is an individual for whom participation in athletics is mandatory and this is true not only from the standpoint of general health, but from the point of view that athletics provide a means of acquiring and improving the necessary professional characteristics. An astronaut must undergo the most varied of physical training.

During a flight an astronaut is likely to encounter the effect of acceleration forces, and his resistance to this factor can be increased by physical exercise. An astronaut must exhibit great volitional characteristics, and these can also be conditioned through athletics. An astronaut must be able to control his body perfectly in space and to coordinate his movements well. How else than through athletics can these characteristics be acquired?

An individual who does not engage in athletics can hardly be expected to be the pilot of a space vehicle. This cannot be forgotten in the training of the astronauts.

Therefore, let us now imagine these future space travelers in a large light park surrounded by blossoming greenery. It is seven o'clock in the morning. The air is refreshing. There are some people in sweat-suits, on a special platform. These are the future astronauts and they are engaged in their morning exercises. Some 20, 30, 40 minutes have passed and one exercise is replaced by another. Everyone is aware of the fact that this collection of exercises does not represent a simple warm-up session before an ordinary work day, but it is rather a specially developed complex of exercises designed to improve

the over-all physical readiness of the individuals involved.

New elements are introduced into the daily morning physical exercises and into the subsequent training sessions as well. The entire system is rebuilt. Here we have a case of a pilot — a quick energetic individual who is a great basketball fan, a participant in this highly active and emotional game — who is, at first, unable to do the exercises requiring strength; as a result, a special program is worked out for this individual. Now, during the morning physical exercises he trains with enviable persistence to condition his body to acquire the characteristics which he lacks; he does exercises with rubber strips, i.e., a special complex of gymnastic exercises has been prepared for him.

This is the way the work day of each astronaut begins in this special institution. After the exercises and breakfast there are special training sessions, mastery of the required theoretical problems, and participation in experiments. Two or three times a week, there is a physical-culture session at the stadium, in a gym, at a swimming pool, etc.

But now let us assume that the required level of physical readiness has been attained. At this point, an individual series of exercises is prepared for each astronaut and these exercises are designed to enable the astronaut to develop those physical characteristics which are required for the forthcoming flight. This series of exercises is prepared with consideration of the features involved in the physical development of the astronauts.

For example, in order better to withstand the acceleration forces that arise during the launching of a space vehicle and during its return to earth, the muscles of the abdominal prelum and of the chest must be particularly strong. This will enable the astronaut to

exhale during a time in which his body is subjected to forces greater than the weight of his body by a factor of 6 to 8. A corresponding sequence of exercises has been selected for the development of this musculature.

It will be necessary, during the flight, to carry out a series of complex coordinated movements under conditions of weightlessness. Consequently, in training for the flight it is necessary to instill the astronauts with the habits of controlling their bodies in space and to carry out all movements in coordination. Physical culture can be of assistance here as well: swimming, diving, gymnastics.

For this reason the special physical training is an absolute necessity for the astronaut from a professional standpoint.

During the period in which the astronauts are engaged in athletics, the pressures on the organisms of these future astronauts are great. If these exercises are not carried out in measured stages and properly controlled, manifestations of over-training and tiring may appear. The individual will begin to lose weight, the desire to exercise will disappear, and sluggishness and apathy will set in; instead of being of benefit, the exercises will prove to have been harmful.

In order to avoid this above-described situation, the attentive and experienced observation of a doctor is required. The doctor is able to determine correctly the correspondence between the physical work being done by a particular individual and the potentials of this individual by observing the changes in the rate of pulse and respiration after the execution of special functional tests in which the physical load is carefully measured and by checking the blood pressure, the electrocardiogram, and how all of these indicators change after the carrying out of physical exercises.

Parachute jumping is of particular importance in training astronauts for [space] flights.

The plains open before us, and we can see three small towers. One of these towers is quite small and we can see a group of people dressed in sweatsuits gathered around this tower.



G.S. Titov on a loop-the-loop swing in an athletic village.

A thick-set small man jumps down from the tower. He lands on the ground with his knees only slightly bent and immediately, and quite unexpectedly, he crumples and collapses on his side. Everyone is looking at him. Then he gets up and says "The most important is not to resist but to give the body a chance to fall either to the left or to the right side."

One after the other, these people in their athletic dress complete their jumps. The instructor carefully keeps each under observation and he immediately analyzes each jump, the individual elements

of the jump, and entire complexes of various movements.

On another occasion we can see people wearing blue suits jumping from another, somewhat higher, tower. Here the complex of movements is more complex and this is understandable; in this series of jumps the individual finds himself in the air for a longer period of time. The instructor demands that the movements should not be restrained and that muscle tension should be followed by muscle relaxation; in addition, breathing should be carried out properly, etc.

The ability of a human being to move on the ground and to be the master of all of his movements has been predetermined by thousands of years of human development. A human being does not have to learn to move, since he is able to do so from the day of his birth and conditioned by the first steps that he takes as a youth. It is a far different matter when we come to movement through the air. In order to jump properly to the ground from a comparatively high tower long and persistent training is necessary. It is only during the training period in which there is an opportunity to coordinate certain elements of movement with others and to inhibit excess reactions, thus making it possible, as a result, for the required forms of movements to appear. With time the jump becomes a well-coordinated motor act. As this takes place, the individual movements that have been mastered and which initially required great attention can now be executed spontaneously; the individual no longer has to think about how he has to proceed, and yet he can do everything correctly, seemingly automatically. The instructor is able to train his students to act in accordance with these thoroughly instilled habits. If we look at these students closely, we are immediately caught by a short well-built individual with a quietly smiling face. He jokes happily and we immediately recognize Yuriy Gagarin. Here is Gherman Titov. Yes,

these are the "cosmonauts." They have been assigned here to practice their parachute jumping.

Parachute training is included in the program to ready astronauts for [space] flights. The astronauts must exhibit habits which will aid them in learning to handle their bodies in space. After all, in the future, particularly in the case of prolonged flights, people will be faced with the necessity of moving in a state of weightlessness. And where else, if not during parachute jumping, can an individual learn to move in a vertical direction without having any support beneath his feet, to change the character of his movements, and to stop at will the turning of his body.

Parachute jumps also serve to condition the will of an individual, his daring, and this is extremely important in the program of training future astronauts.

Finally, the ability to jump must be developed because a parachute drop is one of the versions by which a man can land on returning from outer space.

Jumps from the training towers represent only the first stage of this training procedure. How does the training program proceed beyond this?

We now find our astronauts engaged in a study of the so-called suspension system of a parachute. They have been strapped into the special straps and fastening devices of the parachute.

The astronauts are listening very attentively to their instructor. Everything is going well. Now these individuals will be given an opportunity to check whether or not they have correctly mastered the rules of parachute jumping under completely safe conditions. This is a new stage — jumping by means of a parachute that is fastened to a cable connecting two towers. This device is employed to teach the

astronauts correct landing procedure. The canopy above the head of the parachutist obeys his every command. By pulling on the proper shroud, thus causing the wind either to fill the canopy or to move over its surface, the parachutist is able to direct, slow down, or speed up the descent. One can also be trained to turn around in the parachute harness in order to assume a necessary position.

Each step of such a training session calls not only for the functioning of mind, but for the functioning of hands and all body muscles as well.

And now the time has come for the start of the first parachute jumps from an aircraft. The first parachute jumps can be permitted only in the case of a weak wind (later on, as greater experience is gained in parachuting, the weather requirements can be lowered).

The aircraft carrying the parachute jumpers takes off.

One of the astronauts steps up to the open hatch. He assumes the required position. There is some tension. He pushes with his legs and on command, without delay, he leaves his support and throws himself into the empty space, suppressing the fear that is rising within him. Once in the air the jumper must execute a precise series of body movements, hand movements, and he must simultaneously keep track of the time in order to open his parachute promptly. The wind is whistling and he is gaining speed; the ground is approaching rapidly and the jumper sees flashes of sky and the distant spinning earth. All physical and moral forces are mustered — this ensures a successful and safe landing.

The future astronauts jump and they gradually increase their time of free fall, i.e., the time before the opening of the parachute, from 5 to 50 seconds. An interval of about a minute seems small, but much that is unforeseen may happen with a person who is falling toward



Yu.A. Gagarin in an aircraft prior to a parachute jump.

the ground at ever-increasing speed. This explains why it was so important to train these jumpers to have complete control of their bodies during free fall. At the moment, during the tension-filled seconds of the fall, these habits are absolutely necessary and they must be executed as virtually instinctive movements.

The person flying through the air is carrying out all of the required movements. The instructor is looking at him and says happily to himself: "Good, good."

The body of the astronaut begins to turn in disorderly fashion (it "goes into a spin"). This is an extremely important moment. A number of special movements must be carried out immediately; the astronaut must roll his body up into a ball and then, in a special manner, spread his hands and feet outward. If this is not done, the air will turn the body and continue to twist it right to the ground.

But the jumper quickly and easily eliminates this possibility and the instructor is again happy for him; the training sessions have produced fruitful results. A spin is dangerous because the canopy of the parachute may fail to open during such a fall.

At the same time the jumper, regardless of anything that might be happening around him, must keep track of the time as he falls through the air. Finally there arrives the second at which he must open his parachute. The opening of the canopy is associated with pronounced deceleration and, consequently, with the appearance of great G forces. The astronaut reacts to the opening of the canopy as he would to a dynamic shock of great force. If the equipment has not been put on in proper fashion, boots, helmet and goggles may be torn away.

But all of this is behind us. The great canopy has opened over the head of the jumper and the downward motion of the body has immediately been slowed down. But this is no time for wandering thoughts, but rather a time for immediate action. The pilot must quickly examine the canopy of the parachute, he must separate the shroud lines, and he must determine the direction of the wind. It is necessary to take over the control of the parachute canopy immediately, and this in addition to everything else, involves the physical work of the hands: the parachute shroud lines are pulled so as to increase or reduce the angle into the wind. The jumper quickly approaches the ground. It now becomes necessary to turn the body in the parachute harness so that the wind is to the jumper's back and the ground is moving directly beneath the legs of the jumper, i.e., this again calls for work with the hands and simultaneously great tension. Now all of the habits that were acquired during the landing conditions simulated in training must be called upon for assistance. A powerful jolt can be softened

by proper landing. Several seconds pass and the jumper is on the ground. He gets up on his feet.

Now the examination begins; the pulse is measured, and so is blood pressure. By means of a dynamometer the strength of the hands is determined. It turns out that they have grown significantly weaker as a result of the great physical work which has just been done. Although this seems strange, the weight of the jumper has dropped some 250-300 g, and in some jumpers we observe that the skin is pale, the pulse rate has quickened (90-96 beats per minute), whereas in other jumpers we see pronounced reddening of the face and extreme sweating of the palms.

The jumpers are examined thoroughly, and their psychological reactions are subjected to particularly careful examination. Some jumpers, immediately after the flight, register an abundance of expressive movements, whereas others grow silent and almost rigid. Even-tempered moods are replaced by stimulation, talkativeness, and even an intensification of a jubilant mood.

All of these data play a significant role in determining the features of the reactions on the part of these future astronauts in determining their physical and psychological stability. This is an important point for both the selection of the astronauts and the conditioning of the required characteristics.

Parachute jumps were repeated many times and in different ways. Individual details were worked out. The future astronauts were trained to select their landing point as well as to carry out landings on water. They are now able to execute parachute jumps, regardless of the complexity of the conditions involved. And all of this, in addition to the variety of other athletic abilities, must be regarded as part of the educational training that is required for their profession.

THE WAY TO THE COSMOS IS OPEN

Up to this point we have spoken in our book about the steps to be taken in the organization of training a human being for space flights and we have discussed the theoretical hypotheses which serve as the basis for this preparation.

On 12 April 1961 the entire world learned of the name of Yuriy Alekseyevich Gagarin, and on 6 August of the same year the entire world became familiar with the name of Gherman Stepanovich Titov, who safely completed flights into the cosmos. And now the reader has every right to ask the question: How were these individuals trained for the execution of their unusual assignments?

The results of these space flights are the best proof of the fact that the first astronauts were completely trained to operate under all flight factors and they were well able to withstand the acceleration forces that arose during the take-off and descent of the space vehicle, and they also reacted without harm to other disturbances, the unaccustomed state of weightlessness, and they exhibited complete readiness to carry out the flights.

All of these properties, as well as the behavior of the astronauts during the flight, might be exclusively ascribed to the proper selection and the well-planned systematic training program. Yes, now we can state that this entire procedure has been completely validated. However, it must be stipulated that the actual conditions and certain features of the execution of the investigations during the training of the first Soviet astronauts for [space] flight differed somewhat from that presented in the book.

Much has been reported in the press, at press conferences, and in scientific reports, on the principles involved in the selection and training of the first astronauts. Much material in this regard is

contained in the books by Yu.A. Gagarin and G.S. Titov; these books were written after the flights. There is no doubt that the first astronauts were subjected to a series of special training programs and tests in which many of the factors that would be encountered in the forthcoming space flight were simulated. This procedure involved centrifuge tests in which the corresponding acceleration forces were produced, and there were tests on a vibration stand, and in an isolation chamber in which the individual was insulated from all external stimuli. Yuriy Alekseyevich and Gherman Stepanovich also were subjected to training on special installations in which versions of flight tasks were worked out. They also were quite active in athletics, etc. We have presented above the justification for the need of such preparation.

The assumption also proved to be true that the first astronauts should be chosen from among pilots. Major Gagarin and Major Titov are combat pilots from one of the most complex branches of aviation, i.e., fighter aircraft. Despite the fact that they are young and completed their schooling only relatively recently, they are nevertheless professionals with "many hours in the air," and this means that they have spent much time in vibrating aircraft during which all actions must be executed in definite sequence under conditions of rigid time limitations. Gagarin and Titov have landed jets many times at airfields, and even the slightest error in the landing of such an aircraft can cost them their lives.

It is important to know the specific features of flying in order to evaluate all of the characteristics which were conditioned in Gagarin and Titov through training in their profession — a profession calling for fast thought and action. A short newspaper announcement to the effect that the entire program was carried out during the space

flight points up the fact that although both of the astronauts were dressed in spacesuits (and this means that they found themselves in situations involving comparatively limited mobility) they could carry out all of their assignments exactly under the new and unique conditions and they did not forget anything and made full use of their time. Yes, it is most feasible to train astronauts who are fighter pilots (at least, for the first flights and for the near future).

* * *

The historic events of 12 April 1961 began for the entire world at nine o'clock in the morning when the first report of the launching of a manned space vehicle was announced. People gathered around loudspeakers and congratulated one another. There were wild demonstrations in the streets and the jubilation was replaced by intense attention, which was again followed by great gladness after the regular news broadcasts. For the people directly involved in the preparation for the flights the work day on the 12th of April began at dawn. Several hours later the rocket was to carry Gagarin into the cosmos.

The astronaut awakened. The procedure of getting him into his equipment before the flight is rather complex and cumbersome.

A doctor fastens small silver electrodes to the astronaut's body. Without producing any unpleasant sensations and without restricting his movements, these electrodes serve as unique doors through which information regarding the cardiac activity of the individual is transmitted.

We have already spoken about the fact that all muscle contractions produce electrical potentials. These are extremely small, only about one ten-millionth of an ampere, with a voltage of one-two millivolts. However, after amplification these biopotentials can actuate a lever which can draw a curve that reflects the subsequent shape of



Yu.A. Gagarin before the launching.

the muscle-excitation wave. For the heart this will be an electrocardiogram, and for other muscles it will be an electromyogram.

Although Gagarin will be far removed from his doctors as he carries out his space-vehicle flight, the electrical signals transmitted over telemetry channels to the earth will characterize the functioning of the heart and the muscles and will aid the doctors in

evaluating the astronaut's condition during the flight. In addition to the electrocardiogram, records were also kept of other indicators relating to Yu.A. Gagarin, i.e., in particular the frequency and depth of respiration.

All of the sensing elements have now been attached. Now the astronaut puts on his thin woolen underwear. Special slits have been cut into this underwear so as to provide an opening for the sensing-element wire leads.

Subsequently, we can begin with getting into the spacesuit which is an air-tight piece of clothing consisting of a soft shell into which a ventilation system has been incorporated and it further consists of a heat-insulation layer which provides for the conservation of heat. Even if the astronaut is called upon to spend more than 12 hours in ice water, he will suffer no unfavorable consequences that are associated with excessive cold if he is dressed in this kind of spacesuit.

This spacesuit makes it possible to provide for a definite air pressure around the astronaut's body; thus the astronaut finds himself in an individual air-tight capsule.

However, at the moment the spacesuit which Gagarin is to put on has not been adjusted for pressure and the spacesuit therefore looks like any ordinary piece of clothing, despite the fact that it is cumbersome; the exception to this conventional appearance is the helmet which is unique in shape — a round metallic sphere — and is provided, in front, with a transparent spherical visor-type face window. Special hinges enable the astronaut to move the visor up and out of the way, thus exposing his face. The visor can be closed automatically or, at the astronaut's desire, manually. In order to do this it is enough to tug at a special cable.

Now let us imagine that the pressure has dropped sharply in the capsule and that the astronaut's life is in danger. Immediately, however, the visor clamps shut with its characteristic sound and simultaneously a special valve is actuated in order to feed air into the spacesuit, thus producing the required pressure. This will save the life of the astronaut.

Much creative effort was required for the development of this unusual form of clothing and all of the complex automatic equipment that is required in conjunction with the spacesuit; we have reference here to the equipment required in order to provide for spacesuit ventilation, for the required pressure regime, and the operating sequence of the automatic devices. The spacesuit must not restrict freedom of movement and the visor must permit good visual observation. Much has been done; however, substantial effort on the part of the designers is yet required in order to make the spacesuit more comfortable and capable of satisfying completely all of the requirements that have been imposed.

But now let us return to the dressing of Yu.A. Gagarin. Well-trained aides assist the astronaut in getting into this cumbersome garment. It turns out that this is not an easy matter, even though the spacesuit has been "individually sewn" and Gagarin has tried it on several times. The last manipulation involves the putting on of special shoes. But this is the simplest step of all. These shoes are large and they can be fastened firmly to the spacesuit. This is an extremely important point, since if this is not done the shoes may be pulled off his feet as the canopy of the parachute opens (if the astronaut is called upon to perform this form of landing) because of the G forces that would arise in this case. The gloves — the last part of the equipment — will be put on in the capsule.

There is much that is unknown that awaits the first man in outer space. Soviet scientists have done everything possible in order to ensure the return of this human being from outer space in one piece and without injury; they have done everything possible to enable him to maintain excellent health throughout the entire flight and to ensure his ability to function and carry out satisfactorily the research program during the entire flight. The scientists have worked hard to reduce the number of the unexpected occurrences which an astronaut might encounter during a flight. And Gagarin knows this. Now he shakes the hands of the people around him for the last time and they gaze questioningly into his eyes. Now Yuriy Alekseyevich leaves them and finally he is alone in his air-tight capsule.

What is he thinking about at this instant? He is, of course, thinking about the fact that he must and wants to return. He has had no doubt about his safe return from the very first days of his training. His conviction of this fact could not help but have been strengthened by his association with the people responsible for the preparation for the flight and this conviction could not help but grow as he became familiar with the remarkable technical facilities that were made available in order to ensure the launching of the rocket, the injection of the vehicle into orbit, and the safe landing of the spacecraft. This conviction was strengthened each and every day of the systematic and thorough preparation for the forthcoming flight. This conviction on the part of Yu.A. Gagarin is as strong as the friendship that exists between all of the people readying this first flight into outer space, as strong as the belief in the power of Soviet science, in the humanitarianism of our society for which a human being is the most precious object in the world.

But does this mean that Gagarin had no other thoughts at all?

Hardly: he is, after all, only human. What would any of us feel if we found ourselves in Gagarin's place? In all probability we would think thoughts such as these: "Will I ever see these people again?" There is no doubt that this heart-rending feeling would intrude on all of the other impressions, and this thought would heighten the solemnity of the occasion and the desire to remember these moments forever.

History knows that new paths have never opened easily before people and that travelers into unexplored territories suffered much deprivation and perished. It is not in vain that the entire Soviet people followed this flight with hope and concern for the fate of Gagarin. It is not in vain that the nation will always honor Gagarin as the first man to penetrate interplanetary space.

We now see Gagarin on a platform in front of the hatch to the capsule and he is gesturing with his hand. He is completely quiet and he is actually smiling. Even several minutes after the frame of the rocket has begun to tremble he is still able to joke; then the jet pilot begins clearly to detect new sounds of superpowerful rocket engines. But even at this point Gagarin, overcome with a feeling of humor, responds to the command "Launch" "Let's go."

This will all take place somewhat later on; at the moment the first astronaut is adjusting his position in the couch inside the capsule. The automatic ventilation and communications systems are connected, and we can hear the click of the harness system being locked into place. There are some parting words, and the capsule hatch of the space vehicle is closed.

Now the astronaut finds himself alone. However, this is of course not the isolation from the outside world which the future astronauts experience as part of one of their training stages and which may occur as the vehicle is launched on an extremely distant

trip, in which case communications with earth would become extremely difficult.

In Gagarin's mind there is no and can be no sensation of separation from people. He hears familiar voices throughout the entire period. The people on the outside are already beginning to receive his transmissions. All of these transmissions are equally heartening because the radio waves carry the continuous report (only slightly muffled because of the great distance): "I feel well, the flight is proceeding normally."

Here inside the capsule Yu.A. Gagarin is able to sense the concern of the great number of people who have prepared his flight at the Cosmodrome, he is able to sense the concern of his Motherland. And this heartening feeling does not leave him at any time during his flight.

During the take-off, Gagarin heard the ever-increasing roar of the great and complex machine in which he found himself. He had, after all, grown accustomed "to hear" the noise made by the flying craft which he had flown earlier, during his days as a fighter pilot. The din produced by a rocket has many shadings; at first, however, it resembles the noise that a human being senses in a jet aircraft. The sound is powerful and it seems to fill the entire capsule, penetrating into the ears.

It is difficult for Gagarin to compare his flight in jet aircraft with his flight in a space vehicle. In the former case he was flying a winged aircraft at a speed of about 700 km/hr. The rocket, on the other hand, was moving at a velocity of 28,000 km/hr. The aircraft's ceiling was one and a half thousand meters, while the rocket had a ceiling of three hundred thousand meters.

The astronaut did not suffer any harm during the ascent phase of

the trajectory of rocket motion in which the acceleration forces and those of vibration acted on his body, i.e., the period during which his nerves were tensed to the utmost. Despite the difficulties, Gagarin carefully carried out all of his assignments throughout the entire period.

The individuals in charge of the flight heard his confident voice over radio. The quiet face of the pilot was visible on a television screen.

The changes in pulse and respiration corresponded to the stresses experienced by the astronaut. Gagarin's pulse rate 30 minutes before the launch was 66 beats per minute. During the last few minutes before the beginning of the flight his pulse rate climbed to 109 beats. This was an indication of prelaunch excitement. As the rocket began to move the pulse rate jumped to 140-180 beats per minute. At the end of the active phase, before entry into orbit, a certain normalization of pulse was observed, i.e., 109 beats; within 10 minutes after the beginning of weightlessness the pulse was 97 beats. All of this is normal for the acceleration forces which Gagarin experienced.

Under conditions of weightlessness, the first astronaut was greatly interested in observing his sensations under these new conditions.

The sensation of the force of gravity of one's own body is such an accustomed feeling that it is, perhaps, even impossible to speak of such a sensation. It is most likely that we know that we weigh anywhere from 50 to 70 kg, rather than that we sense this weight. And thus the disappearance of weight immediately makes itself felt.

"Everything has suddenly become easier to do, there is a general sensation of unusual ease. Neither my hands nor my feet, nor for that matter, my body, seemed to be mine," said Gagarin later on. He ob-

served this somewhat strange state for inhabitants of the earth with amazement; you have the impression "that you are neither sitting, nor lying, but somehow suspended in the capsule."

You have but to lift your eyes and you will see the cosmos through the observation window; there is darkness, and there is a black sky and the earth. Down below seas and mountains flash by. Gagarin was gladdened by the variety of pleasant colors he saw on our planet, encircled by a halo of transparent light-blue atmosphere. He observed how this light-blue strip gradually darkened and finally turned into the coal-black color of the sky.

The ability to observe and note all occurrences in the outside world as well as the capacity to observe and evaluate personal sensations and one's own condition are extremely important and necessary characteristics for an astronaut. It is not sufficient simply to be able to feel in this case, but rather one must understand what he feels, he must be able to determine the most important factors, he must be able to evaluate his perception, he must be able to describe what he sees, and he should not forget anything. This is based on a wealth of perception and requires tremendous inner control.

In the case of Yu.A. Gagarin all of these characteristics are better expressed than in anyone else, and this is extremely important. After all, Gagarin must aid the scientists in arriving at a number of conclusions regarding the effect that certain flight factors have on the condition and psyche of a human being, and he must be able to tell about the nature of his motor reactions during the flight, as well as about other sensations that are specifically unique under the conditions of a state of weightlessness; in addition, he must be able to tell about the quality of the functioning of the equipment and apparatus aboard the vehicle. Many of these questions are covered

in the book by Yu.A. Gagarin "The Road to the Cosmos."

The minutes of this unusual flight in weightlessness are passing by. Already very much more time has passed than in aircraft flights in which weightlessness was produced for short periods of time. How does Gagarin feel? How does weightlessness affect the brain and nervous system of a human being; after all, the brain and nervous system of a human being clearly reflect all changes taking place in an organism? The brain and nervous system of a human being are complex organs which control the great variety and expediency of the mutual relationships of the human being to the surrounding world.

Various nerve endings (receptors), upon being stimulated, "capture" individual properties of the things that surround us, and carry these in the form of stimulation — through the nerves — initially to the spinal cord and then to the cerebral cortex. The processes of stimulation and inhibition take place in the brain, old traces are revived, new links are formed, and as a result the received pulses are sensed, and knowledge and thought follows. Signals proceed from the cerebral cortex over the corresponding nerves to the various organs and tissues which are "the ones which carry out the incoming directives."

All of this tremendous work carried out by the microscopic mechanisms which make up the very most complex structures of tissues, cells, conduction paths, and synapses have been adapted for functioning under terrestrial conditions under which they are affected by the force of gravity, in which colored pictures, and sensed and unsensed sounds replace one another, and in which day is replaced by night, etc. Many of these conditions are absent in outer space. Will the human brain be able to function here, in its new surroundings, as well as on earth?

Throughout the entire flight of the space vehicle "Vostok-1" extensive medical-biological intelligence was transmitted to earth in accordance with a definite schedule, and the nature of the man's reactions was established. People conversed with the astronaut and looked at his image on a television screen; in addition, they kept his movements under observation. They were ready, at any instant of time, to come to his assistance and, if necessary, they were in a position to give immediate commands to the automatic systems which controlled all of the complex mechanisms of the space vehicle. But this did not prove to be necessary.

The flight demonstrated that all of the autonomic processes were executed normally under conditions of weightlessness and the astronaut's brain functioned just as on the ground. Describing his sensations Yuriy Alekseyevich did not note any unpleasant gravitational manifestations. His orientation was not disrupted. The astronaut was able to carry out a variety of special movements. These movements were included in the flight program in order to reveal the nature of changes in motor responses during weightlessness. We can draw the conclusion that coordination of motion is not disrupted. Gagarin, finding himself in a state of weightlessness, kept records, operated the required switches, and he drank and ate.

Consequently, the hypothesis which stated that we can anticipate substantial disruptions of orientation in space, coordination of movement, etc., under conditions of weightlessness have not been borne out as a result of this flight. However, we must bear in mind that the flight lasted only 108 minutes and Gagarin himself is an individual who exhibits great resistance to the effect of flight factors. This is borne out convincingly by the data obtained during his training for the flight.

Here we see Yuriy Alekseyevich looking at his watch. Soon the vehicle "Vostok-1" must begin its descent. And again, the astronaut is overwhelmed for the n-th time by a feeling of great satisfaction. After all, the flight tasks have been carried out completely. His well-being and mood continue to remain good and he could continue his stay in the satellite vehicle. It now becomes clear to Gagarin that he will, through his landing, bring a remarkable piece of information to the people on the ground: there are no basic obstacles in the effort to conquer outer space.

Several months pass after this noteworthy event. Yuriy Alekseyevich feels marvelous. Physiologists continue to study his electrocardiogram, taken both for a state of rest and after measured physical exertion. Step by step they investigate the state of his internal organs, the condition of his nervous system, and they conduct a variety of clinical and biochemical analyses.

The first astronaut had entered the unexplored and he experienced many unusual factors personally. That is why the scientists are again, some three to four months after the flight, confronted by the following question: perhaps the astronaut's organism is giving rise, at this very instant, to some undiscovered ailment?

We are again at the clinic in which Yuriy Alekseyevich was examined before the flight. Again the examinations are extremely attentive and persistent. And again, as before, the conclusion is concise: "He is healthy."

The first manned flight into outer space has been completed. This flight will go down in history forever. This flight will be the subject of much writing, and people of all ages and in all countries of the world will recall this event. We can say with a feeling of pride that this flight represents a triumph of Soviet science and that the first

astronaut was a Soviet pilot, a simple Russian man.

What then are the fundamental problems which had to be resolved in this first remarkable space flight? Without touching upon the many purely technical problems, we can state the task of the vehicle piloted by Gagarin as follows insofar as this pertains to man:

to determine how man will be able to withstand the various factors of space flight for a period of an hour and a half during a single revolution of a satellite vehicle about the earth;

to check the operating reliability of the systems which provide for the necessary conditions for a human being to exist in the capsule of the space vehicle and to check all of the facilities that are designed to provide for flight safety;

to study and evaluate the systems designed to record and monitor the astronaut's state of health;

to check the efficiency of the adopted selection and training system for the astronauts.

All of these assignments were carried out.

As a result of an analysis of the medical-biological information received from on-board the space vehicle and on the basis of the report submitted by Yu.A. Gagarin, as well as on the basis of the data produced by the examination of the pilot after the flight, we can draw the following conclusions:

man can withstand the conditions of weightlessness completely satisfactorily for a period of about an hour, and he is able to resist the harmful effects of acceleration forces, noise, vibrations, etc., during both the injection and descent phases. Under conditions of weightlessness lasting for about an hour the ability of a human being to work is preserved, as is the coordination of his movements and the clarity of his thought processes;

the over-all condition of the astronaut Yu.A. Gagarin remained completely satisfactory throughout the entire flight. Changes in the physiological indicators during the active phase corresponded to the stresses which were acting upon him at that time. No changes in the state of Yu.A. Gagarin's health were noted after the flight;



G.S. Titov during his training for the flight.

the life-giving and medical-monitoring systems functioned normally during the flight;

Soviet scientists, engineers, and technicians made it possible for the astronaut to return safely to earth and the vehicle landed in the designated region.

Thus the first flight was able to demonstrate the most important point, and namely, that it is basically possible for man to travel to the cosmos, and this flight also confirmed the validity of the scientific course being followed by Soviet cosmonautics. However, this flight was only the first step and served only to open the window through which could be seen the distant prospective future flights to the infinite reaches of the universe.

A TWENTY-FIVE HOUR SPACE FLIGHT

Just a short while ago it was not known how the state of weightlessness affects the organism.

The remarkable flight of Yu.A. Gagarin in an orbit around the earth first demonstrated to the world what man experiences under conditions of weightlessness. But Gagarin spent only slightly more than an hour and a half in outer space.

How a man would feel under conditions of prolonged weightlessness remained a mystery even after Gagarin's flight.

Gagarin's good health was a unique "pass" in effect authorizing a longer flight.

And such a flight was carried out.

The twenty-five-hour space flight of Gherman Stepanovich Titov exceeded the most daring of scientific expectations.

What happened during this flight? What did Titov feel during his stay of an entire day under conditions of weightlessness? What was the scientific significance of this experiment?

We are now able to arrive at certain general conclusions regarding the effect of weightlessness on the human organism.

... The noise of the engines that functioned during the take-off

phase has abated and an unaccustomed quiet sets in. The vibrations disappear. The astronaut has entered into a condition of weightlessness. G.S. Titov unexpectedly at this instant feels as if he has turned over and is flying with his feet up in the air. But he quickly recalls where "down" and where "up" is in the capsule, and this unusual sensation immediately disappears.

For an instant, that about which we spoke earlier actually took place. No longer sensing his own weight, the man "lost" his orientation in space. The systems which provide for coordination of movement became disoriented under conditions of weightlessness. With the disruption of the accustomed flow of pulses from the vestibular apparatus, the cutaneous receptors, and the remaining organs, the pilot lost his capacity to estimate his position in space for an instant as he relaxed his visual control, but his visual impressions immediately "rescued" him.

Now let us imagine an astronaut in the capsule of a space vehicle prior to the launch. His body is in a stable position. The spacesuit makes the figure look unusually large, and this applies particularly to the unmoving hands and legs. The head is covered by an air-tight helmet. Near the lips, on both sides, we can see small round devices through which the astronaut's speech is transmitted. He wears special gloves on his hands. In this form Gherman Titov looks like an explorer in a science-fiction story.

The cabin of the vehicle "Vostok-2" in which he now finds himself was designed, in terms of dimensions, only for a single individual. The soft shades of the colors on the inside do not tire the eyes.

The couch has been positioned in the center of the capsule. In front and above the couch there are observation windows — windows through which it is possible to look out into the cosmos.

But first let us describe the couch. It is unusual in shape, installation, and even in purpose. In form the couch resembles an elongated sofa. Its support surface follows the reclining portions of a human body and it has been lined with soft plastic pillows. It is quite comfortable to lie on such a couch. The astronaut sits in this couch, he lies down here, and he also sleeps on this device. But the couch has additional functions as well. In actual fact, this is a complex unit designed for a variety of purposes. There are emergency reserves of food in the couch, in addition to radio devices, an oxygen reserve, and ventilation facilities by means of which air can be forced through the spacesuit in order to remove the heat generated by the organism. In case of need the couch can be used to eject the astronaut from the capsule and (together with the spacesuit) protects him against the furious onslaught of the approaching stream of air.

There is much complex equipment in the capsule: there are systems for the control of pressure, humidity, and gas composition. They maintain the optimum conditions for life. The design of the equipment distributed throughout the capsule has been checked out thoroughly in accordance with the physiological-hygienic and technical requirements. Everything has been taken into consideration here, including the fact that the human organism absorbs various quantities of oxygen, depending on the nature and intensity of the work being carried out, and that the body releases various quantities of moisture. Nervous tension alone has an effect on these indicators.

The instruments are designed to follow automatically such changes, adjusting to any new operating regime. They can raise or lower the temperature of the air and the humidity of the air. As a result of the precise functioning of the automatic equipment the air temperature in the capsule of the space vehicle "Vostok-2"



In training.

varied only slightly ($15-22^{\circ}\text{C}$) regardless of the conditional changes taking place on board during the flight. The relative humidity was maintained within a range of 30 to 40%. The quantity of oxygen was not permitted to drop below the norm.

A great many impressions await an astronaut during a flight — these impressions are both of the usual and of the unconventional variety; there is the cosmic rather than the terrestrial sun, there are bright and unblinking stars, the narrow moon crescent quickly floating by the observation window, etc. All of these observations are now possible without the atmospheric cover which always dims the brightness of all colors. There are also new sensations to be ex-

perienced by the body itself; weightlessness is an unusual sensation. Next to the couch is the instrument panel and the levers, switches, and vehicle-control keys; in addition, there is an entire range of responsibilities that must be carried out at specific times as part of the rigid daily program. The assignments are intended to clarify a variety of scientific questions. All of this calls for great attention, self-discipline, the ability to set everything else out of one's mind, and to concentrate entirely on the problem at hand.

Such psychological characteristics, already well developed in pilots, are even further expanded in the case of an astronaut.

The instant that the space vehicle entered the orbit and weightlessness set in, Titov was overcome by a happy mood. Such a psychological state, naturally, yields the most favorable background for the normal physiological activity of an organism.

There are, of course, cases in which such a "wonderful mood" does not objectively correspond to the state of the organism. For example, here is a pilot in a pressure chamber in which the air has been rarefied to correspond to an altitude of 5000 m. He says that everything is proceeding well, he laughs gaily, and he jokes, but at the same time an observer can see that his lips are turning noticeably blue, his facial features have sharpened, his pulse has speeded up to 90-100 beats per minute, and it is becoming increasingly more difficult for him to breathe. Here we have a direct example of a divergence between the true state and the individual's mood. An exuberant mood in this case is a result of the effect produced on the central nervous system by oxygen starvation. This can be explained by the fact that in connection with the disruption of the inhibition process in the cerebral cortex the stimulation process begins to predominate and the analytical-synthetic potentials of the brain are reduced: self-control

is disrupted, and the individual ceases to be aware of danger, all frightening aspects are set aside, and we can observe a state of heightened well-being, or so-called euphoria.

However, the condition and mood experienced by Titov during the state of weightlessness did not disturb him in any way in carrying out his various scheduled assignments accurately and he was able to preserve his ability to work fully, etc. Consequently, Titov experienced the emotion of usual stimulation throughout the entire flight. Let us remember that Gagarin noted excellent well-being and an alert state.

But man must work under conditions of weightlessness. An investigation of man's ability to work during a space flight was therefore one of the most important assignments. Can Titov execute the complex movements required to control the orientation system of the satellite vehicle and will his coordination of movement be disrupted? Will the astronaut be able to evaluate his situation and react correctly to it, etc.? Titov's flight was to provide the answers to these questions. The resolution of these problems was of outstanding importance from the standpoint of the future conquest of outer space. But how is one to evaluate the ability of the astronaut to work during flight? Would it be necessary to propose special methods and to work out unique procedures?

The answer is extremely simple. Professor V.I. Yazdovskiy stated at a press conference devoted to the flight of G.S. Titov that the astronaut's ability to function was studied on the basis of his control of the space vehicle and the systems designed to maintain the conditions for his vital activities... It was also possible to render a judgment regarding the state of his capacity to work on the basis of the quality of his radio communications with the earth and the precision with which he executed his flight tasks.

Ability to work during the flight was studied in the widest possible sense of this word. Titov was given assignments which made it possible to determine as widely and as thoroughly as possible all of the potentials of human activity under conditions of weightlessness. He had to carry on conversations with the earth and to carry out simple motor operations; in addition, he had to control the orientation system of the vehicle, and this required complex coordinated movements. In addition, he had to keep records. It was immediately possible on the ground to learn about the nature of certain of the operations carried out by the astronaut through the telemetry channels whereas information on other operations was gathered by special instruments aboard the vehicle; it was possible to arrive at a conclusion regarding certain other operations through an analysis of the astronaut's actions as they were observed on the ground.

Here we see Titov making his report to earth. After a minute he begins the execution of his next assignment. Now the assignment has been completed. A hurried experienced glance at the hands on his watch and the pilot picks up a log; the required notation appears on the paper. After a certain period of time, the astronaut begins a new assignment. And thus strictly according to the schedule, everything proceeds in its accustomed businesslike rhythm (a procedure that had already been repeated many times during the training sessions).

During the flight, Titov was directly responsible for the execution of such important activities as the monitoring of the operation of the equipment which provided for normal vital activities, and this activity on his part called for great attention.

These "intelligent" automatic devices are able to maintain the required conditions within the capsule independently. If anything of

an unexpected nature occurs, a special light begins to flash on the signal board.

If these deviations from the norm are dangerous in nature, then in addition to the flashing light there is a sound signal which immediately draws the astronaut's attention to it. This makes it possible to gain time and to prevent an emergency condition. There are instruments to indicate the magnitude of humidity, as well as the temperature and gas composition of the air in the capsule, etc. The astronaut employs a definite sequence in order to scan the changes in instrument readings.

Titov checked the manual control of the vehicle twice: at the beginning of the flight, approximately one hour after entering a state of weightlessness, and subsequently during the seventh orbit.

We now see the astronaut switching off the automatic control for the orientation system and switch on the manual system. You should not think that from this point on the entire existence of the vehicle depends on the pilot. This does not happen to be the case. The satellite continues to move as before: with the same velocity and in the same orbit. However, the pilot can now incline the satellite to the right, to the left, turn on a side, turn over, or in other words he can orient the vehicle in various directions with respect to the earth.

And this is extremely important. The fate of both the satellite and the astronaut depend on the orientation of the vehicle at the instant at which the descent command is given; a few incorrect movements of the hand and the vehicle, instead of beginning its descent, may fly off forever into interstellar space.

The astronaut places his right hand on a convenient handle and makes a small movement. The vehicle inclines; the astronaut exerts

a minimum amount of additional pressure in the same direction and the roll is intensified.

Titov keeps his eyes glued to the light-blue "eye" of a special instrument. Has the vehicle reacted properly to the series of minor movements? Has the vehicle assumed the required attitude? Yes, it has assumed the necessary attitude. The pilot, continuing to actuate the lever, experiences great satisfaction.

Characterizing Titov's activity under conditions of weightlessness on the basis of the obtained data Professor V.I. Yazdovskiy at this same conference stressed that despite the great complexity of the flight and the flight assignments, Gherman Stepanovich Titov's ability to work throughout the entire flight was maintained at a rather high level.

However, it should be pointed out that good ability to work may be preserved, at times, even in the case of a generally poor state of health. Under great tension and a feeling of responsibility, a sick or tired individual can nevertheless carry out excellent work. Volition and cognizance of duty control the actions of a human being who may actually be facing the danger of death.

However, it would be incorrect in this case to maintain that Titov's activity was a result of such a mobilization of all of his physical and moral strength during this flight which was so carefully followed by the entire world. A comparison and accurate analysis of all of the data makes it possible to state with conviction and without fear of contradiction that the astronaut was not subjected to any excessive stresses or states of illness. The changes in his physiological functions were direct functions of the gravitational forces he was called upon to withstand, and his condition was in complete accord with the situation and conditions of the flight.

The absence of any excessively painful stresses is confirmed not only by the fact that Titov functioned in exact accordance with the schedule at various instants during the flight, but it is also confirmed by the post-flight condition and behavior of the pilot. The astronaut himself reported that his condition was satisfactory throughout the entire period of the flight and he did not find it difficult to control the vehicle. "Everything can be done in flight," said Titov, "including writing, reading, and it would, probably, even have been possible for me to draw a sketch."

Such is the general hopeful significance of the scientific materials obtained during the flight of G.S. Titov.

Indeed, in describing movement under conditions of weightlessness, we have spoken of the reactions of the astronaut who found himself in a stable initial position. It will, however, be more difficult for a person floating freely in the capsule since he will have to learn to move and steady himself in order to remain in a stable position. In principle, however, this problem can be surmounted.

The most negative phenomenon encountered by Titov during the flight is the occurrence of unpleasant sensations that are associated with vestibular disturbances. Apparently, these disturbances are a result of unusual pulsations to the central nervous system from the vestibular apparatus. As has already been pointed out, under terrestrial conditions signals indicating the position of the body in space are emitted from this area. Under conditions of weightlessness the normal function of the vestibular apparatus is disrupted and this, apparently, produces various neuroreflex reactions and unpleasant sensations.

If an initial compact position is assumed and all sudden movements are stopped, such sensations can be made to disappear. The

astronaut did not experience the sensations during sleep, since this is a time during which the human brain is in an inhibited state.

These unpleasant sensations, caused by changes on the part of the astronaut's vestibular apparatus, compelled the scientists to consider a number of new tasks for future research into the state of a human being under conditions of weightlessness. The assurance of a complete state of well-being for a man during a flight is the primary goal of Soviet scientists. Regardless of how perfect the automatic equipment, it cannot replace a human being: only people will be able to overcome and conquer outer space. Therefore science must continue to study and develop all of the necessary conditions under which it will be possible to achieve the successive prolongation of manned flights into outer space.

As is well known, G.S. Titov's flight provided the first opportunity of studying the features of the daily cycle of human life under conditions prevailing in a space vehicle.

The schedule called for the evening meal to be taken during the third orbit, but the astronaut did not feel much like eating at that time. Apparently, this was a result of stimulation during which time all desire to eat is lost. It is possible that the unpleasant sensations associated with the vestibular apparatus were responsible for this loss of appetite. However, the schedule had to be carried out. Titov opened his food container. This container carried special tubes which, from the outside, looked like tubes of toothpaste or cream, but they were larger than these by factors of 4 to 5. The astronaut selected one of these little tubes which were nicely shaped and pleasant to touch, but "weighed absolutely nothing."

Prior to the space flights of dogs and before the special investigations that were carried out aboard aircraft there was some fear

that the act of swallowing would become difficult under conditions of weightlessness. After all, swallowing is accomplished by the simultaneous contraction of many muscles (of the tongue, of the soft palate, the cheeks, and the throat). All of these must occur in a definite sequence and they must, at the same time, be strictly coordinated. It is known that in the case of certain diseases the act of swallowing is impaired: the muscles responsible for swallowing lose the required rhythm and the food enters the nasal and respiratory tracts. It turned out that the act of swallowing under conditions of weightlessness, however, is fully possible and that all of the muscles required for this act function normally. This had also been confirmed during the flight of Yu.A. Gagarin who was also able to eat and drink during the flight on schedule. Only after such confirmation did it prove possible to send a human being into outer space for many days at a time.

Here we see Titov gently pressing against the end of the tube and squeezing a semiliquid mass of high-calorie soup-paste onto his tongue. He swallows without any difficulty. He is even able to swallow freely a more viscous mixture — a slightly different liver paste. Finally, the third course is a pleasant sweet-sour liquid that completes this first cosmic meal. There was also some specially prepared bread whose small pieces, wrapped in cellophane bags almost did not grow stale. When the astronaut wants to drink he has water at his disposal. It is only necessary for him to place a mouthpiece in his mouth and then to press on a lever. The water in the tank is kept under slight pressure and, despite the state of weightlessness, begins to flow spontaneously. When he has had enough to drink he must stop this flow of water in sufficient time in order to prevent the outflowing and accumulating balls of liquid from entering the capsule, which would be intolerable.

G.S. Titov fell asleep in accordance with the schedule. In order not to disturb the astronaut the special radio stations stopped their transmissions. It became semi-dark and quiet in the capsule and we could see the motionless face of the astronaut, with his eyes closed, on the television screen.

During this time the scientists observed with particular care the state of the astronaut's organism. Sitting in front of the equipment which was transmitting a variety of data over telemetry channels, they saw the radio beam which carried the signals to earth and they examined intensely the records relating to pulse and respiration and the astronaut's electrocardiogram.

On waking up the astronaut completed his "toilet" and he made his first report to earth after resting; thereupon, he began his physical exercises. After resting and exercising Titov felt better and he was ready to face the forthcoming tests — after all, he still had to complete five revolutions around the earth.

And now the command for descent has been given. The vehicle is properly oriented. The rocket engine has been started and gradually the vehicle's velocity is braked. The satellite has entered the descent phase. During the period in which the vehicle was entering the dense layers of the atmosphere Titov was attempting to carry out detailed observation of what was happening on the outside. He saw through the observation window how the light-pink color surrounding the vehicle gradually darkened into scarlet, violet, and finally turned into crimson. The temperature inside the capsule was normal during this period, but flames were blazing all around it. The vehicle seemed to be flying in a cloud of high temperatures. Even the heat-resistant glass in the observation windows began to grow yellow. It was "both beautiful and frightening" writes G.S. Titov;

after all, there were only a few centimeters of specially prepared glass that separated the man from the destructive effect of the forces of friction that generated the roaring blaze on the outside.

How much self-control is required in order to maintain complete control and not surrender to fear when one is aware of the dangers involved in the descent of a satellite vehicle?

Powerful and varied gravitational forces act on a human being during descent. The vehicle descends ever lower and lower. Now it is flying over the territory of the Soviet nation and outlines of familiar rivers and large collective-farm fields are flashing by.

Titov withstood well the completion of the flight during which the space vehicle moved through the dense layers of the atmosphere and during which time the astronaut was again affected by gravitational forces; in addition, he also withstood well the landing process which called for considerable concentration of will power and physical strength.

The twenty-five hour space flight was completed successfully — the vehicle landed exactly in its designated region.

* * *

The space flights of Gagarin and Titov serve as proof of the strength of our society which developed the leading scientific establishment in the world and these flights serve as clear and convincing proof of the fruitfulness of the labor of the people engaged in the building of communism.

The Soviet government spared nothing in order to develop the facilities and equipment which would guarantee the safety of these space flights and which would provide the best possible of training for the astronauts. The nation equipped the first astronauts for their unusual travels and everyone understood both the necessity for and

the tremendous importance of these flights. Glory awaited the first astronauts.

Gagarin and Titov are the heroes of this new age which will sweep aside the many difficult and unnecessary disturbances of the past on the way to great conquests.

It was, of course, very much easier for Gagarin and Titov than it was for the courageous Russian peasant Kryakutniy who climbed into the sky with a primitive balloon, and it was considerably easier for them than it was for the first of our theoreticians in the area of jet engines, i.e., Kibal'chich; they also found it easier than it was for Tsiolkovskiy who struggled under the conditions of prerevolutionary Russia for the idea of conquering outer space. These adherents to the idea of conquering outer space experienced much obscurity, persecution, and deprivation in the name of their efforts.

... Here we see Yuriy Alekseyevich Gagarin standing in an elevator, getting ready to board his space vehicle. Provisions have also been made in this well-designed vehicle to return an individual to earth even if he should lose consciousness.

However, Gagarin was prepared to encounter any and all difficulties, despite the fact that no single individual had, as yet, flown such a vehicle into outer space and no one knew how the entire complex of space-flight factors would affect a human organism.

Titov experienced the same thing. The assignment which he had to carry out was, on the one hand, facilitated by Gagarin's example, and on the other hand, was a more difficult test as a result of the great duration of the flight, which rendered Titov's flight a qualitatively new stage in the effort to conquer outer space.

Gagarin and Titov had many opportunities to refuse to carry out the flight at any stage of the selection and training procedure, and

finally before the actual flight itself. But they did not do this. With great persistence these Soviet pilots passed through each of these various forms of tiring and frequently difficult training procedures. And looking at them, one gets the basic impression that these people were unhesitatingly ready to sacrifice themselves to the idea of conquering outer space and that they were possessed by the passionate desire to become astronauts.

After the launching of the Soviet artificial satellites of the earth various institutions began to receive numerous letters from people of various professions who expressed this passionate desire to fly into outer space. We would remind the reader at this point that no one had any idea as to what awaited a human being at these cosmic altitudes. These people were courageously offering their lives to science in order to be participants in this great new endeavor.

Here is one of these letters:

"I am reading all of the literature pertaining to space flights and I have done everything possible to familiarize myself with the technical aspects of such flights; in this connection, I am keeping up with all scientific achievements. It is my passionate desire to participate actively in the conquest of the cosmos. I am prepared for anything and I do not require either glory or recognition; I will undertake any experiment, regardless of the risk." And there were many thousands of such passionate and convincing letters. These letters indicate the popular heroic desires of our people; this is, however not a source of wonderment, but rather quite usual.

Many people feel that Gagarin and Titov are very lucky and they regard them with healthy envy, thinking: "I could have, perhaps, done as well as they in the cosmos." To these people we have to say that Yuriy Alekseyevich Gagarin and Gherman Stepanovich Titov are not

only the lucky ones who were selected, but the people who worked long and hard in order to realize their dreams.

The romance of alluring and beautiful distance. But now it has become reality and there are difficult days ahead. Getting up early, training, exact execution of all instructions directed at the conditioning and training of many characteristics, tests of an organism's endurance in the face of many powerful and unusual disturbances, etc. Participation in important experiments, physical training, much serious and intense work on theoretical problems, unbroken discipline at all times — such were the days of Gagarin, Titov, and the remaining astronauts. And each hour and minute thus becomes not some pleasant affair of danger and romance but a matter of minute detail and persistent work.

Such are the first representatives of this new profession of astronaut.

We must speak about the joy of life and optimism and the total spiritual health — the results of proper upbringing — which our hero-astronauts exhibited and which are characteristic of the entire younger generation of Soviet people. All of these human characteristics have been instilled in the land of socialism.

As you look at Gagarin and Titov you understand clearly that glory cannot spoil such people. They are just like the thousands upon thousands of simple Soviet people. And we love this simplicity, modesty, and comradely sensitivity in them. We know that no matter how well developed their ability to associate with people, they will always be embarrassed by the thought that they are the subject of so much conversation and thought.

And our hero-astronauts will always remember that their achievement became possible only as a result of the Soviet science and con-

temporary engineering which developed this amazing rocket-wonder that is obedient to the human will and that their glory is directly connected with the triumphant glory of Soviet science.

Gagarin put this well: "I wanted to sit down and write that this effort was not mine alone, but that tens of thousands of scientists, specialists, and workers had prepared for this flight which any one of my astronaut comrades could have carried out."

Our book has now come to the end. There is little that remains to be said. We would want to remind all people desirous of becoming astronauts that the flights of Gagarin and Titov served only as the start in the effort to conquer outer space.

It is clear that with further improvements in technology and with the appearance of space vehicles capable of carrying more than one passenger, and with greater complexity in the scientific assignments to be carried out by participants in "stellar" trips, people of professions other than that of pilot will have to be selected, including highly-skilled representatives of the various disciplines of knowledge who have a desire for scientific work and experience in the field of research. As a result of engineering achievements, apparently, the effects of unfavorable flight factors will be reduced and their effect on an organism will be diminished. Our knowledge about the specific features involved in space flights will be increased. All of this will make it possible for many individuals interested in the area of astronautics to realize their dream of personal participation in the conquest of outer space. Many true sons and daughters of our Motherland will have an opportunity to participate in this great effort. The glorious tribe of Gagarin and Titov will multiply.

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